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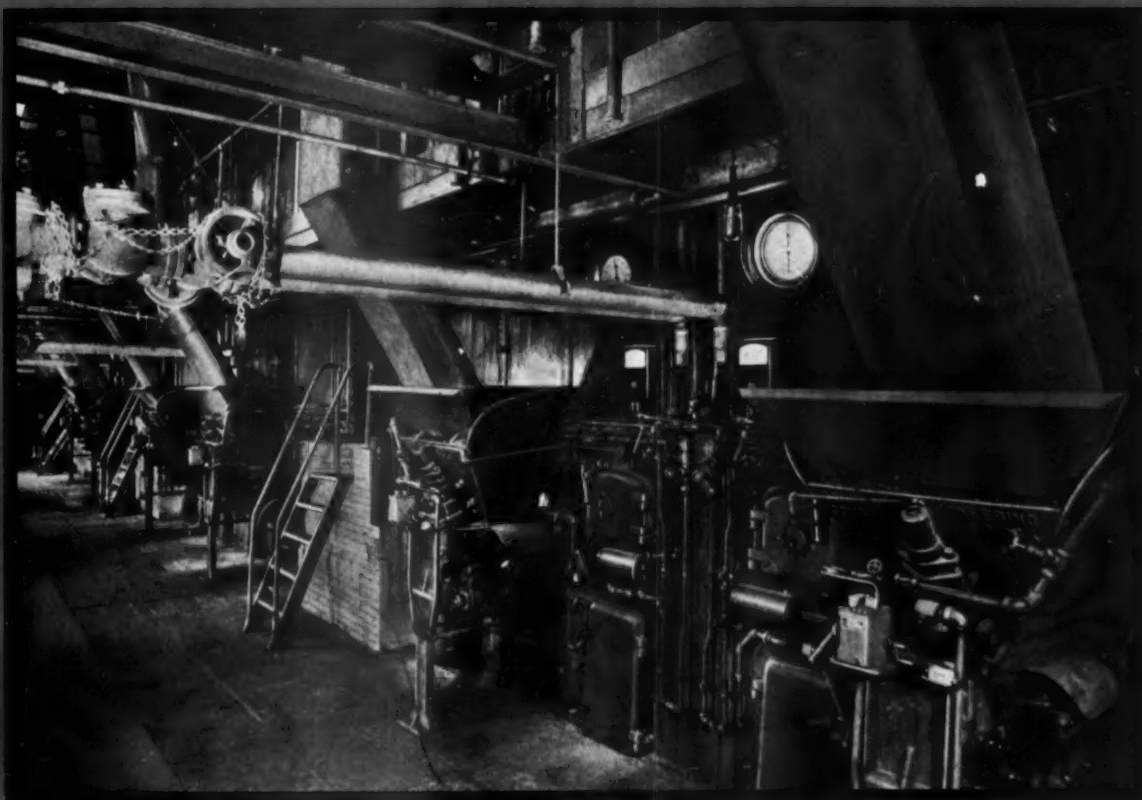
COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

July, 1947



Single-retort underfeed stokers serve this railroad power plant

A.S.M.E. Semi-Annual Meeting

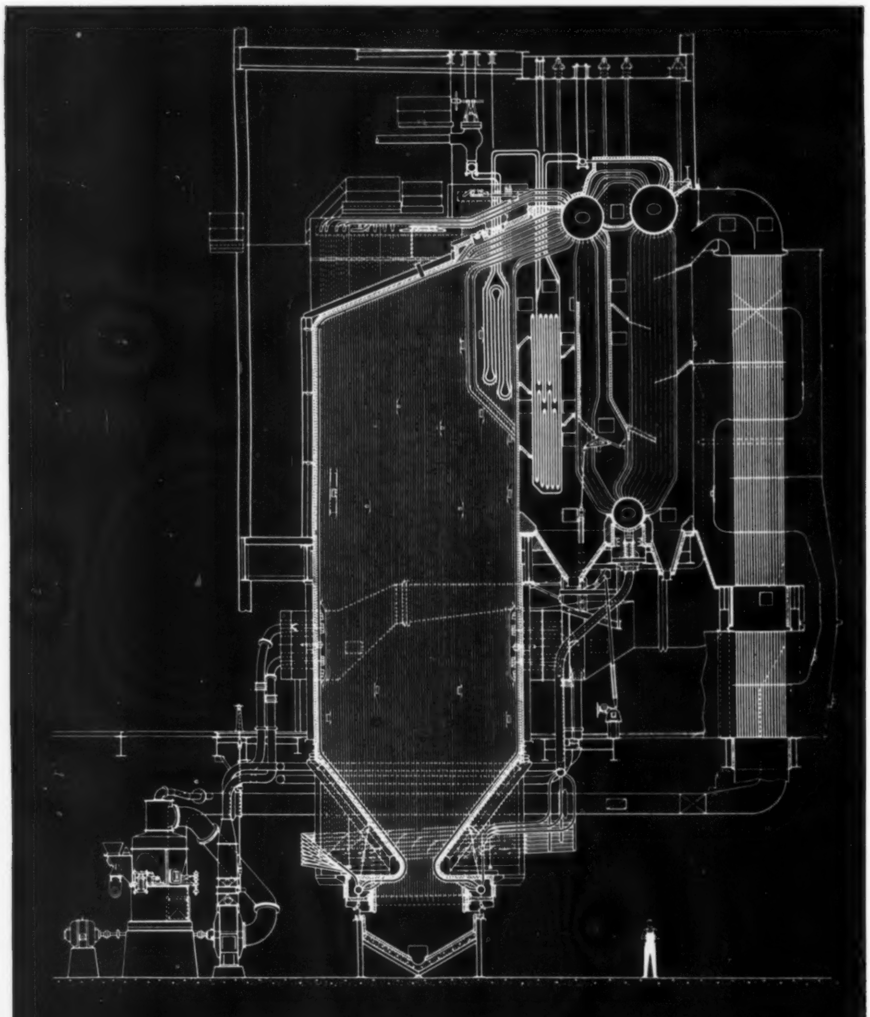
Construction Cost Trends

Silica Deposits in Steam Turbines

Recent C-E Steam Generating Units for Utilities

MEREDOSIA POWER STATION

CENTRAL ILLINOIS PUBLIC SERVICE COMPANY



THE C-E Unit, illustrated here, is now under construction in the Meredosia Power Station of the Central Illinois Public Service Company at Meredosia, Illinois.

It is one of four duplicate units for this station designed for a pressure of 950 psi, a total steam temperature of 910 F and a maximum continuous capacity of 285,000 lb of steam per hr.

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COMBUSTION

DEVOTED TO THE ADVANCEMENT OF STEAM PLANT DESIGN AND OPERATION

VOLUME NINETEEN NUMBER ONE

CONTENTS

FOR JULY 1947

FEATURE ARTICLES

EDITORIALS

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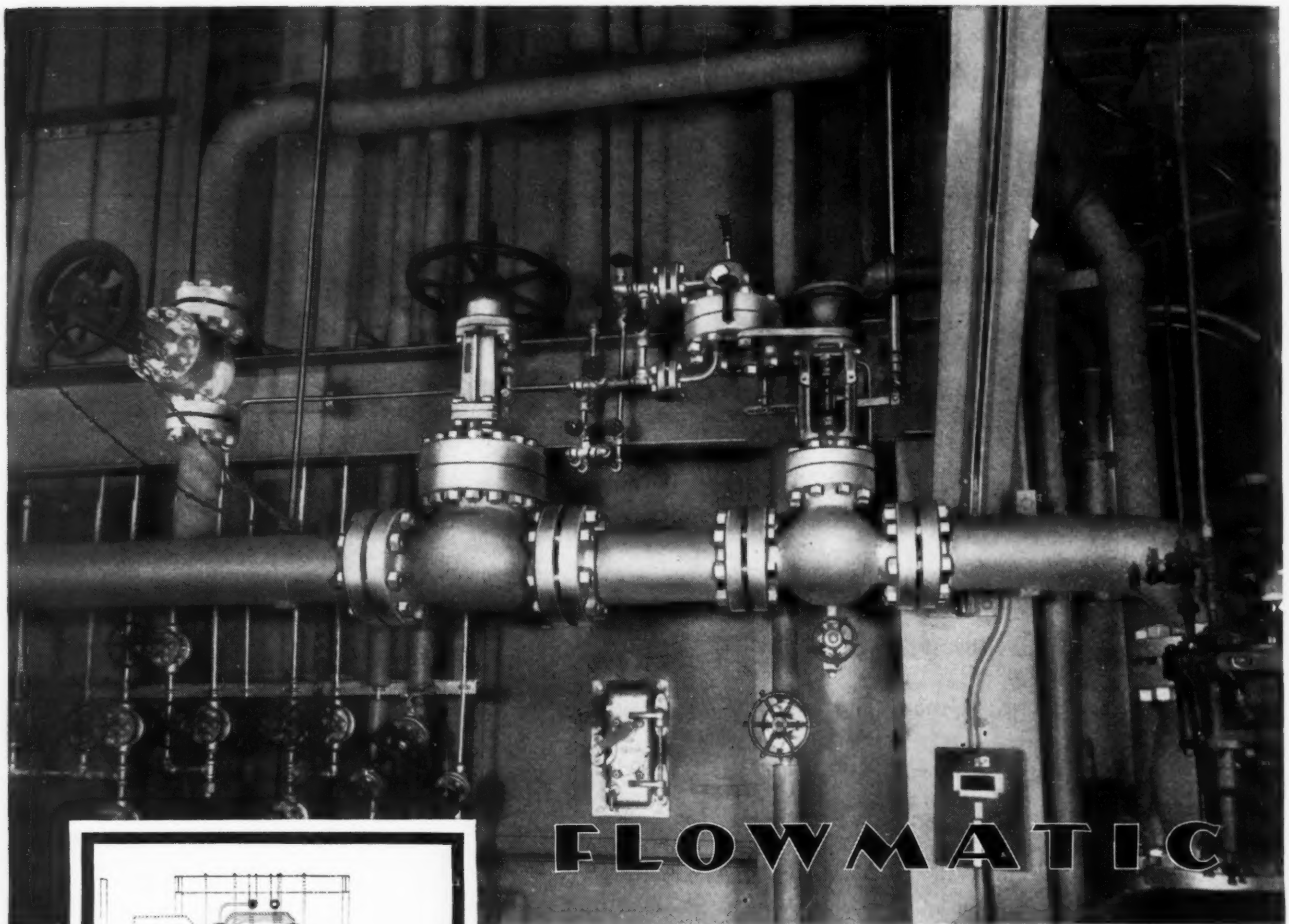

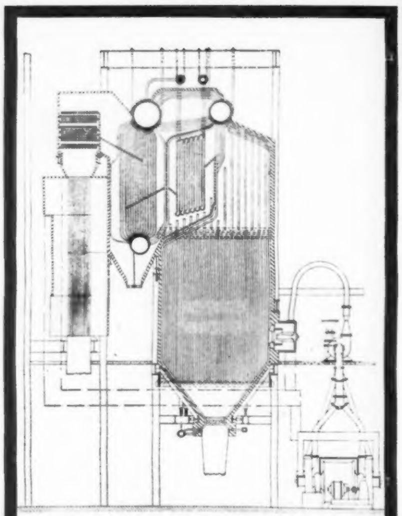

Unit 3: 650-psi, 825-F Foster Wheeler boiler; 220,000 pounds per hour. Units 1 and 2 are similar, with half the capacity.

at Greenidge Station . . .

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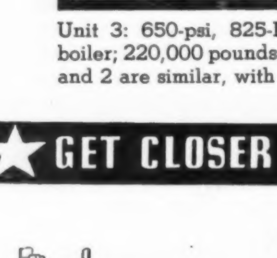

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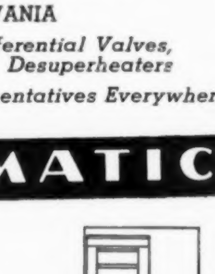


EDITORIAL

The Free Enterprise System

The American free enterprise system represents the world's newest and most liberal thought whereas communism and socialism are reactionary throwbacks to the era of serfdom. It is impossible to replace the initiative of millions with the dictatorship of a few without lowering the living standards. When this is done a very inferior product results. Marx attributed the low living standard of the masses 100 years ago to the greed of employers, but in fact it was caused by the low productivity of the worker.

The foregoing points were brought out in a talk by Charles E. Wilson, president of General Motors, at the recent A.S.M.E. meeting in Chicago. Comparing the free enterprise system to an automobile, with the hope of profit as the spark plug and ignition system, and the fuel as the productive effort of all workers, Mr. Wilson declared that "some people feel that the fuel has a pretty low octane number which cuts down the power and makes the engine knock a bit." Although the free enterprise engine is efficient and useful, he believes that it can and will be improved just as the inefficient automobile engine of 25 years ago was improved. He is against discarding this proved, efficient engine that gave this nation the world's highest living standard and replacing it with some imported type from east of the Rhine or even from England—like, for instance, the jet engine which has only one spark plug, the state, and depends for its power on a blast of hot air.

Increases in productivity have resulted from new tools, new processes and new inventions, all of which have been made available through reinvestment of profits. Technological progress in America has increased the value of goods produced per worker from five hundred dollars in 1849 to six thousand dollars in 1939. For the same period the average mechanical horsepower per wage earner in manufacturing establishments has gone from 1.15 to 6.40. These figures would also indicate an increase in dollar value of goods produced per horsepower.

The hope of profits is what gets the job done with a minimum expenditure of man-hours and material. With the cost of these principal ingredients of production at an all-time high, manufacturers must operate at a high level of efficiency. More than ever a high level of productivity per worker is needed in order to provide the profits needed for development of new processes, inventions and improvements of working conditions.

Mr. Wilson voiced a plea for affirmation of faith in a liberal and free competitive system and warned against the efforts to find political short cuts to prosperity without work.

Management of industry by government and the practice of subsidizing special groups in one form or other, while seemingly attractive to many individuals, have not proved conclusively that such practice benefits the majority of Americans in the long run.

Lewis Wins Again

A coal strike, which many feared would follow return of the mines to their owners on July first, did not materialize. Industry was spared the paralyzing effects of another coal stoppage; but the price was unusually high and John Lewis achieved another victory—this time the greatest of all. He set his sights high and gained practically everything he demanded, including a wage increase three times that granted lately by many other industries, and double the welfare fund that will amount to sixty million dollars yearly and the disposition of which he will dominate as chairman of its custodians.

Introduction of the "willing and able to work" clause was aimed at evading that portion of the Taft-Hartley Act rendering the union liable for strikes in violation of the contract. Also, there are some other stipulations that seem at variance with the Act. How such subversion may be interpreted by the Courts must await a test case, especially if others attempt to follow suit.

The provisions of the new labor law do not become effective until August twenty-second, and apparently the negotiators for the steel industry, at a period of peak demand, did not care to risk a stoppage pending application of the new law, or the probable time involved in securing subsequent Court rulings. However, it is not the steel industry nor the coal companies who acquiesced in Mr. Lewis' demands that will bear the burden; it will be industry and consumers in general.

Various estimates have placed the increased mine cost of bituminous coal at seventy-five cents to a dollar a ton, which will mean a further increase by the time the coal reaches the consumer. There was a time when such increases could be largely offset by improved efficiency of equipment and operating economies, but technical advances over the last decade have greatly reduced such possibilities. Moreover, the price of competitive fuels has lately advanced and their availability is limited.

With the increased coal prices utilities are likely to encounter difficulty in holding the line as to rates, despite greater demand and improved load factors; process industries will have higher manufacturing costs and steel products will advance. Thus the effect will be cumulative and inflationary—all because of the insatiable demands of one individual.

Charles E. Wilson addressing the Monday Night Dinner

A.S.M.E. Semi-Annual Meeting at Chicago

THE 1947 Semi-Annual Meeting of the American Society of Mechanical Engineers was held at the Stevens Hotel in Chicago, June 15 to 19. With the excellent program provided and more than 1200 in attendance, this meeting was most successful. In addition to the many technical sessions there were numerous other events including special lunches and dinners, which included talks by Charles E. Wilson, President of General Motors, H. J. Rose of Bituminous Coal Research, Robert R. Wason, President of Manning, Maxwell & Moore and Board Chairman of the N.A.M., and several plant inspection trips. The local section and the various committees who made this meeting the success it was are to be commended.

Plant inspection trips included the Corwith Works of Crane Co., Melrose Park Works of International Harvester Co. and Calumet Station of Commonwealth Edison Co., as well as a visit to Armour Research Foundation.

President's Address

President O'Brien, addressing the first luncheon meeting on the topic "Broader Vistas," foresaw improved economic and professional status for the engineering profession, and widening opportunities for public service through increased cooperation of the national engineering societies. A medium for such concerted action exists in the Engineers Joint Council, made up of representatives of five national engineering societies.

This body, in collaboration with the National Society of Professional Engineers, has recently issued a report of its work on national labor legislation. It succeeded in having incorporated in the labor bill provisions that engineers should have freedom of choice in accepting or rejecting collective bargaining; that they should not be arbitrarily included with the employees of nonprofessional grade, as exists under the Wagner Act, that where collective bargaining is deemed the proper procedure engineers should have the right to organize their own professional bargaining unit; and the engineer, being a professional man, should retain the right of individually approaching management in negotiation of employment conditions.

Further mentioned by President O'Brien were the returns from questionnaires sent to the 21,000 members of the A.S.M.E. and 31,000 members and student members of the A.I.E.E. seeking opinions on exempting professional employees from provisions of the National Labor Relations Act. Over 18,600, or 60 per cent of the A.I.E.E. members replied of which 84 per cent favored exclusion. Of the 10,245 A.S.M.E. replies 76 per cent favored exempting engineers.

All answers were broken down into age groups and different engineering levels and it was found that, despite the foregoing percentages, many junior and student members felt that they need protection in the form of someone who is persuasive and articulate to represent them with management. As to this attitude, President O'Brien expressed the opinion that what young engineers need most is a friendly professional orientation in their adopted field of work.

At the first Power Session there were two papers—one dealing with economies in the design of utility power plants, by **E. H. Krieg** of American Gas & Electric Service Corporation; the other on the economics of industrial steam plants, by **B. A. Lininger** of E. I. duPont de Nemours & Co.

Central Station Design

While the primary objective of power plant design is to secure the highest overall return on the investment, Mr. Krieg cautioned against making first cost and oper-

ating expense the sole criteria. High availability is of prime importance regardless of load factor, for neither low first cost nor fuel economy means anything to a plant that is shut down.

One of the major economies in first cost is adoption of the single-boiler, single-turbine combination, provided special attention is given to availability and reserve capacity. Designing for high availability costs more, as the lower heat transfer rates in the boiler require more surface and more liberal proportioning of the equipment, but such extra costs for single-boiler-turbine units are in most cases justified by such savings as:

1. A decrease in reserve capacity.
2. The unit cost of equipment generally decreases with size.
3. Building and foundation costs decrease materially with the single boiler.
4. Operating labor costs decrease.

The type of furnace bottom of pulverized-coal-fired boilers must be selected to suit the range of coals that are available as well as the range of load. A wet bottom is ideal for low-fusion ash coals and a high load factor that will keep the furnace hot; but if the coal changes to a high-fusion ash type and loads of less than half rating must be carried for long periods, the ash will not melt and run out. In such cases it may become necessary to shut down the unit and dig out the ash.

Maintenance costs are usually less as the unit size increases. One means of economizing on turbine-generator cost is to follow the A.S.M.E.-A.I.E.E. Preferred Standards for units from 11,500 to 60,000 kw, as such machines will cost up to 7 per cent less than nonstandard turbines. Above 60,000 kw a thorough study of the various available types is warranted as a generalization cannot be made that the improved efficiency of a cross-compound turbine is worth the higher cost over a single-casing type. The service demand availability of large turbines has greatly increased in recent years and 95 per cent or higher is the present objective.

With reference to condensers and circulating water systems, Mr. Krieg cited what had been done at several plants of the A. G. & E. System. For instance, in extending Philo Station insufficient river water was overcome by placing the condensers in series, with accompanying saving in piping; and at Logan additional capacity, despite insufficient spray pond makeup, was obtained by superposing a high-pressure turbine on the existing plant.

At the Atlantic City and the Scranton Stations, it was possible to hang the condensers directly to the exhauster of the 25,000-kw turbines, thus saving the cost of springs or expansion joints and the condenser foundation. Tie rods take the twist caused by changes in circulating water flow so that load is not transmitted to the turbine. However, for large units an expansion joint between the turbine and the condenser is favored to afford more certain relief from strains on the turbine.

Condenser costs are reduced by using long condenser tubes, as it is usually cheaper to manufacture the longer shell of decreased diameter.

With reference to piping and valves, and again citing what had been done at some of his company's plants, Mr. Krieg stated that the boiler stop valve had been omitted between the boiler and the turbine emergency stop valve on the 2300-psi high-pressure extension to Twin Branch Station. At Windsor in 1938 anchored emergency stop valves were first used on a 60,000-kw topping turbine and this practice has since been followed on subsequent turbines. By so doing, the piping design can be started earlier without waiting for turbine outline prints. Also at Logan in 1936, and at subsequent stations, a large saving was made by providing only one boiler feed line from the feed pumps to the boiler.

Valve costs may be materially decreased by employing one size smaller than the pipe, for valves cost so very much more than pipe that a higher pressure drop through the valves can be justified.

Finally, fuel or thermal economy, while worthy of patient search, should not become mere Btu chasing, and low fuel cost requires an awareness of the trend of future fuel costs.

Discussion

One discusser stated that during the 1930's there was a trend toward more efficient turbines—some with as high as 23 stages. More recently the tendency has been toward fewer stages which results in a slight decrease in efficiency but offers other operating advantages. The older turbines are now being used for peak service. Reference was also made to the practice of deaeration of the condensate in condensers, thus eliminating the necessity for deaerating heaters.

Another emphasized the importance of first cost versus operating economy when he pointed out that most boilers in the eastern section of the United States use their equivalent cost in fuel in one year.

Industrial Steam Plant Design

In his paper discussing the "Economics of Industrial Steam Plants," Mr. Lininger considered the problem from the viewpoints of the executive, the plant operator or supervisor, and the designer.

Assuming that steam is required for heating and process and power to drive the machinery, the executive requires that these services be provided at minimum capital cost, imposing no unnecessary operating cost burden that will interfere with high overall return. This involves a study of the problem of whether a steam-generating plant should be provided or whether steam and electricity should be purchased. A reasonable agreement for the supply of steam and electric power by a utility would require the industrial customer to pay certain fixed and variable operating charges plus fixed charges on the total allocated capital. These would include a return on the investment in addition to depreciation, and would be payable regardless of the load placed on the utility by the customer.

A hypothetical example was given which indicated lower annual operating cost for the private plant, but in this case the saving indicated only a 3.6 per cent return on the investment. In such a case, it was pointed out, the executive must decide whether such a rate of return will justify the investment, for rates of return required for an industrial venture ordinarily should be higher than those currently acceptable in the money markets as there is no guarantee of repayment to the lenders.

From the operator's viewpoint maintenance of ade-

quate service at all times is paramount and shutdowns have definite monetary values. Also, power conservation is an operating function that is necessary if investment in power facilities is to be kept low; and economies in power utilization often permit increased production without adding power facilities, thus increasing the return on the investment.

In some cases equipment modernization can be justified by operating cost reductions, to illustrate which an example was cited that produced a net return of 21.8 per cent. It is the operator's responsibility to initiate this type of economic analysis.

Coming to the designer's viewpoint, Mr. Lininger listed the principal objectives as minimum investment, minimum operating costs and insurance of adequate service without shutdown. The last mentioned objective requires additional investment over the minimum which the designer can determine. If this is satisfactory both the executive and the operator will be happy.

It was further pointed out that a boiler manufacturer may propose an installation having a small furnace and stoker to be operated at the limit of heat transfer and burning rates in order to make a low bid. Although such low-cost equipment is desirable, it may require investment in dust-collecting facilities and may also result in high operating costs because of limitations in fuel selection. It is the overall cost picture that must be considered and there are times when sales engineers could have turned failure to success by proving that a high bid would result in lower overall costs.

Discussion

It was pointed out by one discusser that the industrial power problem is more complicated than that of a public utility and there is no single lowest common denominator of kilowatt-hours of service. The problem is further complicated by the fact that the industrial power plant is geared to the manufacturing operation which in some cases becomes obsolete at an early date.

Another indicated a need for more study of plant shutdown costs and stressed the importance to the manufacturing process of maintaining all power services.

Furnace Performance Factors

This presentation, the second given on the subject, covers in four parts an investigation by the A.S.M.E. Special Research Committee on Furnace Performance Factors of the variation in heat absorption in a pulverized-coal-fired steam-boiler furnace. As the work of the committee is continuing, the current report includes significant data procured and analyzed up to the present.

The subject investigation was carried out on Boiler No. 11 at the Tidd Plant of The Ohio Power Co., Brilliant, Ohio. The boiler is designed to operate at a maximum continuous rating of 475,000 lb of steam per hour at 1375 psig and 925 F at the superheater outlet and is tangentially fired by vertically-adjustable pulverized-coal burners having a tilting range from 30 degrees above the horizontal to 30 degrees below.

Part I—Variation in Furnace Heat Absorption by Measurement of Exposed Tube Temperature

This part, by **L. B. Schueler,** American Gas & Electric Service Corp., covers the measurement of temperature of the exposed side of furnace wall tubes and discusses the results obtained. Variations in heat absorption as affected by burner position and excess air were investigated. The paper describes locations of center line thermocouples on the hot sides of wall tubes at 135 points in the furnace. These were used in connection with a 140-point Micromax recorder and consideration of the data forms the bulk of the report. Conclusions therefrom are briefly as follows:

The variation in furnace-wall tube absorption, as determined by tube temperature measurement, shows overall heat absorption to be materially influenced by (*a*) evaporation, (*b*) ash accumulation, (*c*) flame position and (*d*) excess air for combustion. All four were investigated and the evaporation, flame position and excess air are directly controllable while the ash accumulation on wall tubes can be indirectly controlled to some extent by the use of furnace-wall soot blowers.

A study of the furnace-wall heat absorption data and isotherms, which are plots of the wall-tube temperatures above saturation base, indicates some interesting conditions described briefly, as follows:

1. High absorption rates are attained in the path of burner flame, as would be expected. This could be unmistakably demonstrated and positioned, as desired, by varying the vertical tilt of the burner nozzles.
2. The heat absorption rate in the burner zone is quite irregular as influenced by periodic accumulation and shedding of ash on the tubes in this area. The effect of this condition on overall furnace performance is very small due to the great diversity in period and magnitude of the action.
3. The tests with various amounts of excess air indicate greater furnace-wall absorption stability at high excess air although highest furnace efficiency would probably be obtained with low excess air and periodic wall cleaning to remove the ash and slag deposits which form more readily.

In general, it is concluded that the tube metal temperatures, as measured, do give a reasonably good representation of relative heat absorption rates throughout the furnace and such information can be of considerable value in analyzing details of furnace geometry, burner design and location, slagging characteristics and numerous other detailed factors.

Part II—Furnace Heat Absorption Efficiency

Heat absorption efficiency of the same furnace, as determined from the sensible heat in the gases at the furnace outlet, was covered in this part by **W. T. Reid,** of Battelle Memorial Institute and **R. C. Corey** of the U. S. Bureau of Mines. The sensible heat was determined from the temperature of the gases, which was measured by traversing the furnace outlet with a high-velocity thermocouple, and from the quantity of gas leaving the furnace, which was computed from the composition of the gas and the rate of fuel firing. Measurements of the actual velocity of the gases, by means of a double-impact pitot tube, accounted for 88 per cent of the mass flow of the gases at the furnace outlet, despite the fact that the patterns of the flow of gases were too complicated to permit measurement of all the flow components by this method. Data are given for the distribution at the

furnace outlet of excess air, gas temperature, and mass flow. The effect on furnace heat absorption efficiency is shown for variations in (*a*) the heat available in the furnace, (*b*) the excess air, (*c*) the angle of inclination of the burners and (*d*) the condition of the furnace with respect to deposits of ash and slag on the heat absorbing surfaces. The data of this investigation were correlated by a modified form of the Hudson-Orrok equation, which relates empirically the furnace heat absorption efficiency to the weight of wet gases at the furnace outlet per unit of heat available in the furnace, and the heat available in the furnace per square foot of projected radiant heating surface.

The entire series of 26 tests were described. These covered wide ranges of conditions affecting furnace heat absorption efficiency. The test methods were conventional, but results were given in more than common detail. A summary of all the various phases of the entire subject thus far is contained in Part IV.

Part III—Variation in Heat Absorption by Density and Velocity of Fluid Within the Tube

This paper by **A. R. Mumford** and **C. G. R. Humphreys,** of Combustion Engineering Company, summarized efforts to determine heat transfer rates by a series of differential static pressure measurements on a single experimental tube, No. 40, in one wall of the furnace, and compared them with rates determined by measurement of the surface temperature of the tube. The latter method showed higher steam qualities at all points. It indicated as the reason for the lower values obtained from static pressures that the steam occupies more of the section near the heat-receiving side and the water more of the section near the casing side where the pressure taps were located. This apparently resulted in an indication of higher density than the average by the pressure tap method. Extension of the connection to

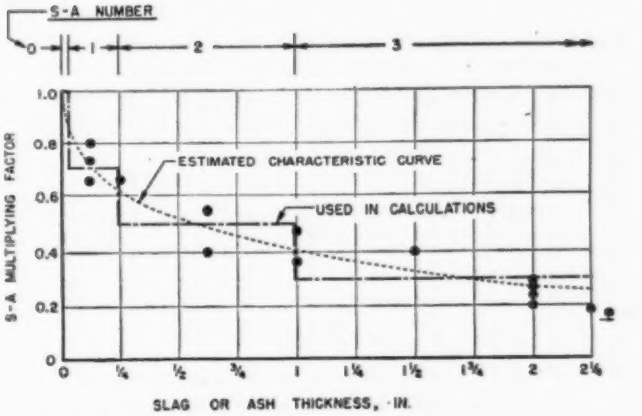


Fig. 2—S-A (slag ash) factors and identification numbers for various slag or ash thicknesses

the hydraulic radius instead of ending it at the inner surface might have increased the derived quality. However, the variations in the difference between the two methods made the coordinating factors derived from the averages of doubtful value. Because the surface temperature method did coordinate well with the difference between the heat input and heat leaving the furnace, it was used as the standard of comparison.

This paper is No. III of a series of four and papers I, II and IV deal with results using thermocouples described in the following article: "Thermocouples for Furnace-Tube Surface Temperature Measurements," C. G. R. Humphreys, "Combustion," Dec. 1944, p. 53–55.

Part IV—Comparison and Correlation of Results

The three preceding sections of the Report are compared and satisfactory coordination is accomplished for the first two sections in the last paper by **A. R.**

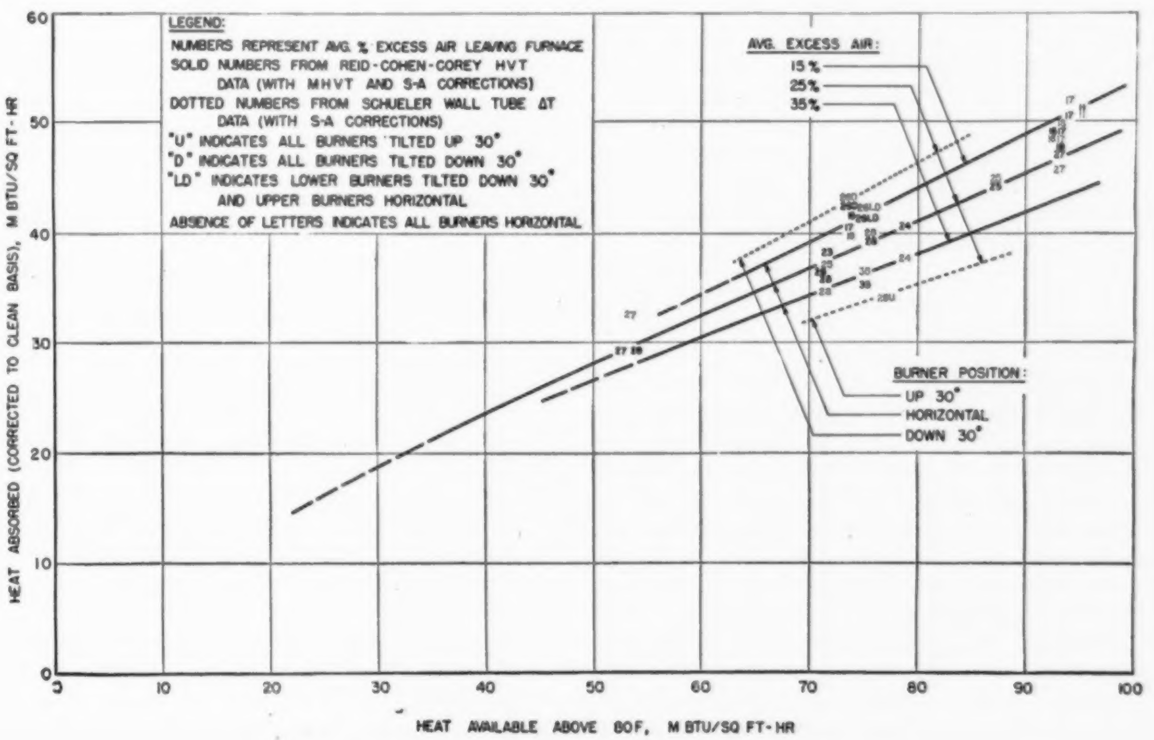


Fig. 1—Heat absorption rates corrected to clean furnace condition through use of effectiveness factors

Mumford, Combustion Engineering Co., and **G. W. Bice,** American Gas & Electric Service Corp. The tube surface temperature measurements show furnace heat absorptions which can be coordinated with the absorptions indicated by the surveys of the gas conditions at the furnace outlet by applying a correction to the gas temperature measurement or by varying the tube to water film conductance. The work reported in sections I and II investigated four major variables:

1. Heat Available
2. Excess Air
3. Direction of Fuel Firing
4. Relative Cleanliness of Water-Cooled Heat-Absorbing Surfaces.

The conventional method of measuring heat absorption is compared with the method using large numbers of thermocouples at waterwall tube surfaces on the fired side.

Fig. 1 illustrates graphically some effects of changes in burner tilt and excess air. The fourth remaining heat variable for consideration was slag and ash on furnace walls. After numerous observations a "Slag-Ash (S-A) Factor" and an "Effectiveness Factor" were devised which, it was felt, might warrant further study. Fig. 2 summarized the final S-A characteristics and the following extracts explain their utility:

1. The S-A factor of a given increment of water-cooled surface, all portions of which are in approximately the same cleanliness condition, is defined as the ratio of the actual heat-absorbing capacity of the surface to the heat-absorbing capacity of the same surface when completely clean.

2. The effectiveness factor of any zone in a water-cooled furnace is defined as the average, weighted according to area, of the S-A factors of all of the separately considered increments within that zone.

Following the same line of reasoning, the effectiveness factor for the total furnace would be the average, weighted according to area, of the effectiveness factors for the various zones comprising the total furnace.

The general procedure used in determining zone effectiveness factors was similar for all zones where prevailing cleanliness conditions were described in sufficient detail in the Furnace Observation Reports. This procedure consisted of estimating the percentage of each wall (or roof or section of outlet screen) covered with slag or ash of each thickness range. Each percentage was then multiplied by the S-A factor assigned to its thickness range, and these were totalized.

The authors conclude this interesting phase of the report by suggesting that the effect of relative cleanliness upon furnace performance represents the most difficult of the variables to evaluate. However, by making thorough observations of all visible furnace heat-absorbing surfaces and interpreting such observations carefully by means of the S-A factor procedure as outlined, the furnace "effectiveness factors" may be computed. By using these effectiveness factors to modify measured heat-absorption rates, performance of the furnace under a theoretical "clean" condition can be approximated. This should permit future comparison of the performance of differently shaped furnaces fired with various fuels, regardless of the relative cleanliness of the heat-absorbing surfaces due to age, cleaning facilities and schedules, load variation cycles, fuel analyses, etc. In this investigation use of total furnace effectiveness factors varying from 0.86 to 0.95 have made possible a much better correlation of data from the various tests than was possible without their use.

Discussion

E. M. Powell, Combustion Engineering Company, in discussing the paper suggested that if the data were presented in terms of gas temperature rather than as absorption efficiency, a greater appreciation of the information might be realized. Temperature of the gases leaving the furnace can be regulated by three variables; excess air, control of ash accumulation on the furnace walls and angle of inclination of the burners. The tests have been planned so that these factors can be isolated and evaluated individually.

He presented calculated furnace temperatures based on the data for the tests, which showed that with a clean furnace there is essentially no variation of gas temperature with excess air. From data collected after several hours of accumulation of ash on the furnace walls it is evident that as much as 73 deg F variation in temperature of the gas leaving the furnace can be expected between excess air values of 15 and 35 per cent. As the tests were run so as to allow ash to accumulate at constant excess air and rating it can be concluded that with 35 per cent excess air practically no ash would accumulate on the furnace walls during the test period since there was no change in gas temperature and the rate of accumulation would increase as the excess air is reduced.

The long-term effect of ash accumulation was shown by one test in which the furnace walls were cleaned by wall blowers reducing the temperature of gas leaving the furnace by 45 deg.

During the ensuing test period of 60 hr the gas temperature reached a peak of 90 deg above that in a clean furnace after which by normal shedding of slag it returned to 45 deg above that in a clean furnace.

Regarding the effect of tilting of the burners it was noted that the temperature of the gases leaving varied as much as 430 deg between a burner inclination of +30 and −30 degrees. Greater variations in gas temperature result from tilting the burners above horizontal than below.

Sulphate-Type Deposits on Boiler Tubes

This paper prepared by **J. F. Barkley, L. R. Burdick** and **A. A. Berk** of the Fuels Division, Bureau of Mines, describes sulphate-type deposits on the gas side of boiler tubes of one of the stoker-fired units at the Naval Gun Factory, Washington, D. C. These deposits found in the boiler passes to the rear of the first pass were a dark gray, very hard and tenacious, somewhat stratified accumulation consisting largely of sulphates. They were very difficult to remove; soot blowing had no effect; they caused considerable draft loss; and were corroding the tubes.

The boiler rated at 140,000 lb per hr evaporation at 195 psi and 570 F was operated at an average 24-hour load of 68,000 lb. Firing was by means of an underfeed stoker with an average burning rate of 22 lb of coal per sq ft per hr. CO_2 at the boiler outlet was maintained at a minimum of 14 per cent.

The coal ran about 21 per cent volatile matter and 7.2 per cent ash on a dry basis. Sulphur content was 0.6 per cent.

Another smaller boiler at this plant, stoker fired with about the same combustion rate but with 12 per cent CO_2 at the boiler outlet, did not produce this troublesome deposit.

In order to obtain more definite information on the character of the deposits 6-ft tubular probes, in which either saturated steam or water at various temperatures could be used, were inserted in the boiler settings.

The deposit obtained at the end of the probe was a white layer largely ferrous sulphate, but with other sulphates and silica. The iron found in the inner layer of the deposit came mostly from the probe as evidenced by loss of metal from corrosion.

To determine whether the steel of the probe was causing the deposit, a nonmetallic probe was employed at the economizer inlet. The deposit found here was typically acid and high in sulphur but was considerably lower in iron content and was of less dense structure. Among the factors involved in the formation of deposits are the effects of SO_2 and SO_3 the relative action of which has not yet been determined satisfactorily.

To analyze for SO_2 and SO_3 in the products of combustion the method described in the A.S.M.E. Power Test Code was carefully followed. Due to the presence of small quantities of copper and a few other metals in the coal ash which were poisoning the benzyl alcohol inhibitor, oxidation of sulphite to sulphate was not prevented. An improved and satisfactory method of analyzing for SO_2 and SO_3, the details of which can be found in the paper, was developed.

It was found during the tests that varying the CO_2 had a marked effect on the formation of these deposits. The accumulation was almost completely retarded when a CO_2 of 9 per cent was carried. It is believed this is due to the sweeping action of the greater amount of fly ash, together with its high traveling speed. By operating the troublesome boiler at 12 per cent CO_2 it was possible to run for a year without draft loss and with only a small accumulation of deposit. This was removed effectively by a water-washing procedure when the boiler was taken off the line.

Discussion

In the discussion which followed it was mentioned that these findings are similar to those encountered at the cold side of air preheaters and also that the smaller particles of fly ash, a higher percentage of which can be expected leaving the boiler and economizer, are higher in acid content. This discusser pointed out the need for continuing this work.

Another discusser told of hard ferrous sulphide deposits found on superheaters of high-pressure boilers where oil firing was employed. In this plant all the regenerative-type air preheaters had to be washed weekly.

Quick Starting of Turbines

This paper entitled "Quick Starting of High-Pressure Steam-Turbine Units" was presented by **J. C. Falkner, R. S. Williams** and **R. H. Hare** of Consolidated Edison Company of New York. It summarizes in detail starting-up procedures for boilers and turbines with more than the usual expedition. The method is particularly adapted to units at plants, where the character of the load is such that some of the high-pressure units must be shut down and started each night.

The authors stated that they appreciate that starting and stopping high-pressure and high-temperature boilers and turbines two hundred or more times per year introduces problems not heretofore encountered. With this in mind, investigations were made to see what could be accomplished in a way that would reduce the heat stresses in both turbine and boilers to a minimum and to reduce the starting cost, which in itself is a considerable item.

The quick starting consists of simply admitting steam to the turbine at a temperature corresponding to that of the main parts of the machine, such as valve chest, heavy flanged joints, top and bottom of casing, etc., after a shutdown period up to ten hours.

The subject of this paper is of considerable interest to many operating men and as space in this report will not permit inclusion of the detailed steps involved, the paper will be abstracted in greater detail in a forthcoming issue.

Discussion

In the discussion that followed, representatives of the three large turbine manufacturers voiced approval of this practice and pointed out that quick starting can eliminate flange leakage and also that there is less chance of distortion during starting up than in shutting down. It was also pointed out that manufacturers were more concerned about the effects of temperature differential rather than its magnitude.

Another discusser told of experience with high-temperature, high-speed marine turbines in naval service wherein far greater stresses are imposed, especially when going from full speed ahead to full astern in a matter of seconds, than generally encountered in land service.

In closing, Mr. Falkner said that his company plans to apply this procedure after longer shutdowns than overnight but they will bring the units up to 550 F by normal procedure first.

Boiler Drum Steel After Forty Years' Service

At the last power session a paper entitled "An Investigation of Boiler Drum Steel After Forty Years' Service" by **H. S. Blumberg,** Chief Metallurgist of M. W. Kellogg Co., and **G. V. Smith** of U. S. Steel Corporation Research Laboratory, was presented. The steels tested were samples from drums removed from service in Waterside No. 1 Station of Consolidated Edison Co., New York, after having been in service since 1902. Operating conditions for these boilers were 200 psi and 388 F.

Several times in recent years there have been proposals that boiler inspection codes be modified to require an arbitrary derating of drums after about thirty years' service regardless of the fact that careful inspection might not disclose any significant loss in metal thickness or any observable deterioration of joints. This might imply that the metal itself undergoes a deterioration in properties.

Although there are a number of different kinds of changes which may occur in metals during service depending on operating conditions, those that could occur in the steels investigated here involve only so-called strain-aging embrittlement and caustic embrittlement.

A careful maintenance program resulted in a very good operating condition of these boilers up to the time they were taken out of service. During yearly overhauls the drums were scraped and were brushed down to clean metal. A gray lead oxide paint was applied to the inner drum walls and, in addition, the surface below the water line received one coat of graphite and fish-oil mixed. Feedwater treatment throughout the like of the boilers appeared to be good.

Samples of plate, joints and rivets from several drums were removed for testing. Plate surfaces had no indication of pitting or wasting away of metal at any location. Rivets and rivet-joint surfaces appeared to be in the same condition as must have existed when the drum was fabricated. In addition to the test samples drillings were obtained for chemical analysis.

To determine mechanical properties, samples were subjected to tension tests, bend tests, Brinell hardness tests and macroscopic, microscopic and magnaflux examinations. To determine any loss in notch-impact strength which would result from strain-aging embrittlement both Charpy and Izod impact tests were applied. Strain-aging characteristics of the metal were investigated. Compared with present A.S.T.M. A-70 steel a slightly greater degree of strain aging was exhibited.

A review of the investigation on this boiler drum material indicates that there is no evidence of deterioration nor signs of general corrosion. Caustic embrittlement is clearly absent. The mechanical properties are similar to those of present-day steels of like composition. There is no indication that serious strain aging has occurred as a result of service.

It was thought that the absence of overall corrosion and caustic embrittlement may be attributed largely to the careful maintenance program. The tests performed in this investigation show that the subject material is susceptible to strain-aging embrittlement, but probably not significantly more so than steel which would today be applied to the same service.

In view of the findings the paper indicates that these boiler drums were still suitable for continued service under the same operating conditions for which they were designed and that derating of the drums on the basis of age alone is not warranted.

Gas Turbines

Papers relating to gas turbines claimed a prominent place on the program. These included the following: "Design Features of a 4800-Hp Locomotive Gas-Turbine Power Plant," by **Alan Howard** of the General Electric Company; "Coal-Burning Gas-Turbine Plants," by **J. I. Yellott** and **C. F. Kottcamp** of the Locomotive Development Commitee; "The Modern Gas Turbine in the Industrial Power Plant," by **J. R. Haskins, Jr.,** of the Union Electric Company of Missouri; "Development and Testing of a Gas-Turbine Combuster," by **A. E. Hershey,** of Westinghouse Electric Corporation; and "Elimination of Waste Products of High Moisture Content in a Gas-Turbine System," by **Prof. J. H. Potter,** Johns Hopkins University.

A 4800-Hp Gas-Turbine Plant

After reviewing some of the pre-war and wartime development work in the field of gas turbines by his company, Mr. Howard described a post-war design intended primarily for locomotives, but applicable to other power plant uses. This unit, as shown in Fig. 3 embodies a simple straight-through, in-line arrangement of compressor, combustion chamber and turbine, with neither a regenerator nor other elaborations of the cycle. It is rated at 4800 shp when running at 6700 rpm with 1400-F turbine inlet temperature. An overall net thermal efficiency of somewhat over 17 per cent is expected when the unit is tested.

The compressor, which is of the axial-flow type has 15 stages and is designed to handle 70,000 cfm through a pressure ratio of 6 to 1. Bunker "C" oil is burned in the six all-metal combustion chambers and the two-stage turbine discharges to atmosphere through the diffusing exhaust hood. It will drive d-c electric generators through a reduction gear and as the power plant forms an integral unit no base is required.

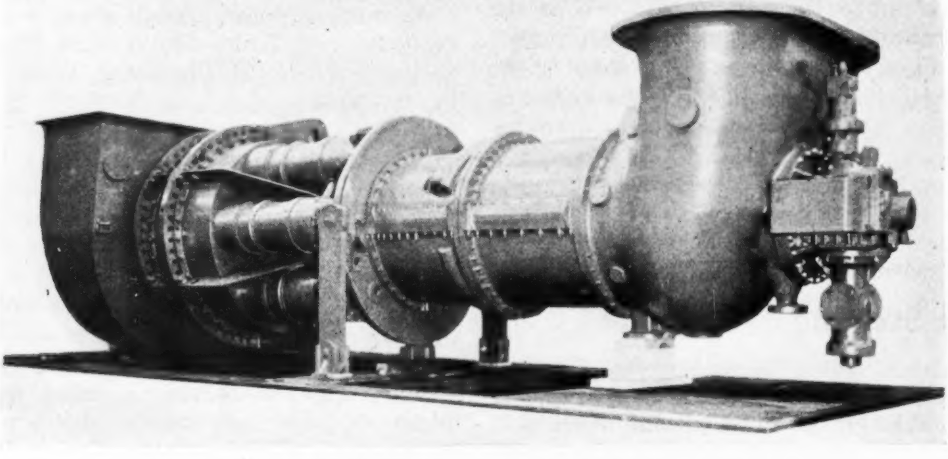


Fig. 3—Sketch of 4800-hp compact gas-turbine power plant for locomotive use

Progress on Coal-Fired Gas-Turbine Plant

Previous papers by Mr. Yellott, some of which have been reviewed in these columns, have told of the work of the Locomotive Development Committee, toward perfecting a coal-fired gas-turbine plant. They have compared such a plant with other types of power plants for locomotive drive, and have described the method of atomizing coal through a nozzle with compressed air. The present paper, while further discussing these phases of the work, also reports recent progress including the results of fly-ash abrasiveness tests at the Institute of Gas Technology, combustor tests at Battelle, the new pilot plant at Dunkirk, and information on the two full-scale gas turbines now on order for delivery in the spring of 1948 for locomotive use.

The fly-ash tests have shown that the air which is cleaned by Aerotec tubes (see Fig. 4) is not abrasive to the alloys used in gas-turbine blades. However, an entirely unexpected phenomenon developed in these tests. When cleaned air was blown at high velocity and low

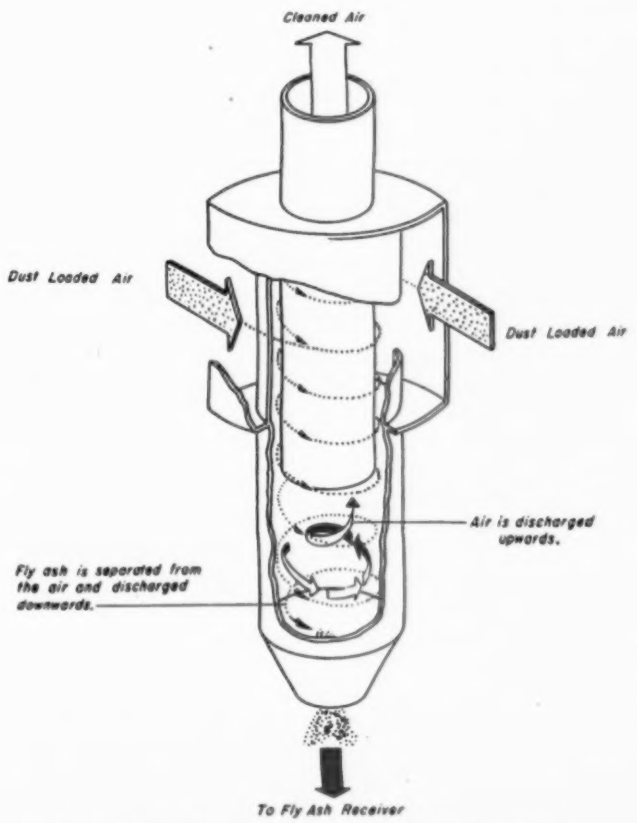


Fig. 4—Principle of operation of the Aerotec Tube

temperature upon turbine-blade alloy specimens, there was no noticeable effect; but as the temperature was raised above 800 F the fine material began to adhere to the test specimens. This adhesion appeared to be a maximum in the range from 800 to 1300 F. Although such deposits can be removed by sandblasting with coarse fly ash which leaves a satin finish to the blades, it was found that they could be removed in a short time by chemical washing. It is planned that disposal of the fly ash from the locomotive will be done at the terminals, and sufficient capacity will be carried to allow the locomotive to run 1000 miles without refueling or discharging ash.

In the pressurized combustion tests which have been underway at Battelle for the last two years, at pressures up to 60 psig, it has been found that pressure introduces no radical departures from conventional burning, except that the combustion rates, in Btu per cu ft per hr, are far higher than at atmospheric pressure because more oxygen is available. In the initial zone heat releases as high as four million Btu per cu ft per hr have been obtained, but at the far end of the combustor the rate drops to about 750,000 Btu. A reasonable figure for design purposes is one million Btu. Fine pulverization was found conducive to high efficiency in small combustors.

Tests are now under way on a pilot plant erected at the Dunkirk Works of the American Locomotive Company where some 60,000 cfm of free air at pressures up to 100 psig is available for testing a combustor with up to 1000 lb of coal per hour. This pilot plant contains all the elements of the coal-handling, combustion and fly-ash removal systems that will be used in the actual gas-turbine power plants. Data on these tests will be presented at a subsequent meeting of the A.S.M.E.

Two full-scale gas turbines for locomotive use are now on order for delivery next spring. One of these is being built by the Allis-Chalmers Mfg. Company. This will employ a 21-stage axial-flow compressor directly driven by a 6-stage turbine. At full load this compressor will deliver air at 77 psia through the air heaters to the separator. Four 1000-hp d-c generators will be driven by the turbine through reduction gears. The second turbine is being built by the Elliott Company. It will be of the four-stage reaction type and will employ a two-stage centrifugal compressor. A single 4000-hp d-c generator will be driven by the turbine through reduction gearing. This turbine is designed to operate at 1275 F.

Gas Turbine for Industrial Power

Mr. Haskin's paper was directed to application of the gas turbine to the type of industrial plant where the process steam demand is not great enough to warrant the generation of the entire power demand as by-product power. Such a gas-turbine installation was defined by the author as consisting of a turbine, a compressor, a generator, a waste-heat boiler and economizer, a fuel system for gas or oil, a combustor, feedwater system and reducing valve for reducing steam from the main header pressure to deaerating-heater pressure. The turbine is considered as limited to an inlet temperature of 1200 F and the economizer should reduce the stack gas temperature to 350 F when the feedwater temperature is 220 F.

The author, assuming a hypothetical case, calculated an overall plant efficiency of over 59 per cent, by employing a waste-heat boiler instead of regenerators to improve plant efficiency. This is less than that of a straight back-pressure steam plant, where there is a fairly good balance between steam and power demands, but is much better than a straight condensing plant and exceeds that of a condensing and extracting installation to the extent that power is generated condensing.

Gas-Turbine Cycle for Waste Fuels

After reviewing current practice in the utilization of several high-moisture waste fuels, such as wood, bagasse,

pulp-mill waste, garbage and other refuse, Mr. Potter suggested a gas-turbine cycle for use with industrial or municipal wastes.

This proposed cycle is represented by the diagram in Fig. 5. Air enters the compressor *A* at 1, and compression is in two stages with intercooling, *B*. The air then enters the heat-exchanger *C* where the temperature is increased. These operations can be followed by reference to the T-S diagram, Fig. 6. Normally the temperature 5′ leaving the heat-exchanger is high enough for use at the turbine inlet; but if not, auxiliary fuel may be employed, the compressed air being routed through the combustor *E* where oil can be burned. Work is done in the turbine *D* which supplies power both to the compressor and for power generation.

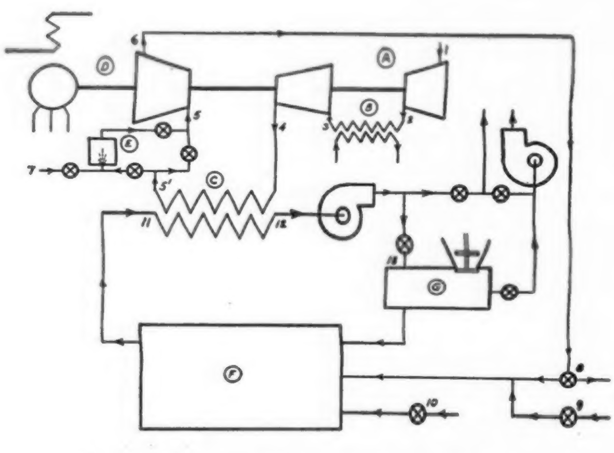


Fig. 5—Diagram of proposed arrangement

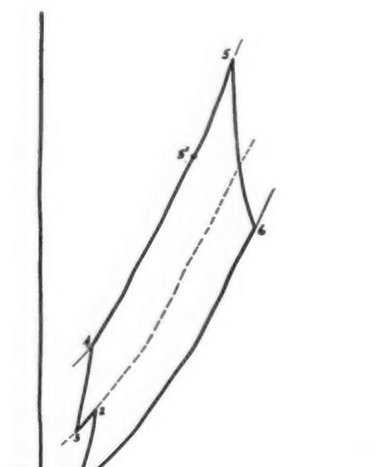


Fig. 6—T-S diagram of cycle

The air leaving the turbine is at relatively high temperature and is sent to the furnace *F* to serve preheated air. The valve *8* makes it possible to bypass the heated air to atmosphere and thus serves as a control device for the furnace. Cold air may be introduced at *9* and further secondary air at *10*. The hot products of combustion are sent from the furnace to the heat-exchanger where heat is given up to the turbine cycle. From *12* the spent gas is delivered to the drier or bypassed to the stack. The moist fuel is introduced into the drier *9* through a suitable hopper device and the moisture content is reduced as the fuel mixes with the products of combustion from the furnace.

It is generally conceded that incinerator temperatures should exceed 1400 F if odors are to be eliminated. In fact, such gas temperatures from 1800 to 2500 F have been reported. The heart of this cycle is the heat-exchanger.

Mr. Hershey's paper dealt mostly with methods of testing and the detailed results of the combustor tests which space here does not permit reproducing.

Coal and Ash Handling

A paper on coal handling with earth-moving equipment by **R. L. Hearn** and **R. F. Legget,** dealing with a solution developed at the synthetic-rubber plant constructed by the Polymer Corporation for the Canadian Government at Sarnia, Ontario, was presented by **E. W. Dill,** power superintendent of this plant.

This has the largest steam plant in Canada. It contains five boilers each of 308,000 lb of steam per hour capacity, requiring up to 650,000 tons of coal annually. As the year's supply of coal must be received at the plant during a period of seven months, storage and handling presented special problems. Daily receipts by water up to 3000 tons were expected. Provision for delivery of smaller quantities of coal by rail was also expected.

In selection of the coal-handling equipment, the following special requirements had to be met:

1. The necessity for continuity of processing required that steam supply be uninterrupted.
2. Economic conditions at the time of construction of the plant made costs an important factor.
3. The possibility of changing to oil fuel after the war necessitated a minimum expenditure for coal-handling equipment.

Other factors involving river navigation and delivery of coal dictated special construction requirements for the wharf.

The possibility of using earth-moving equipment for handling coal was considered in view of its similarity to granular soil plus the fact that coal is lighter and possesses lubricating qualities.

The equipment used to handle the coal after being discharged from the belt conveyors leading from the wharf consists of a 15-cu yd LeTourneau scraper hauled by a Caterpillar D7 Tractor.

In all, the movable equipment includes one bulldozer, three tractors and three carry-all scrapers.

Coal is taken from point of discharge and spread by the carry-alls in relatively thin layers on the coal pile, which covers an area approximately 400 by 1000 ft to depths up to 40 ft. The coal is scraped off the pile in thin layers and pushed to the hopper leading to the crusher-

house conveyor by a second tractor which is fitted with a bulldozer.

Aside from the basic question of cost of this equipment the following definite advantages are realized:

1. This mobile equipment is standard and can be duplicated easily.
2. Operation of the heavy tractors on the coal pile compacts it to densities otherwise not obtainable, which condition minimizes temperature rise in the coal.
3. Due to the action of the scrapers in reclaiming the coal, a thorough mixture of the various types of coal delivered is obtained in the bunkers.
4. Due to compacting the coal and elimination of the dangers of spontaneous combustion, it is possible to build coal piles to heights not otherwise obtainable. A height of over 100 ft has been successfully used at another plant which uses the same method of coal handling.

The largest single shipment of coal to the plant was 12,000 tons and the record for unloading is 1260 tons per hour. It has been found possible to operate the entire coal-unloading, storing and reclaiming operation with one crew varying from 5 to 7 men.

Based on a 5-yr period for the depreciation of all equipment, the unit cost of handling the coal from the end of the discharge conveyors of vessels to the crusher house, proved to be 18.4 cents per ton. This figure consists of 10 cents for operation, 1.5 cents for interest on capital investment and 6.9 cents for depreciation. However, the present operating costs are materially lower than this figure. It is believed this method of coal handling compared to ordinary methods is unusually economical.

The second paper at this session was on "Coal and Ashes Handling at the Modern Boiler House" by **G. A. Gaffert** of Sargent & Lundy, in which various problems involved in the design of such systems were discussed. It was pointed out that in addition to the mechanical requirements to be met, consideration must be given to the architectural aspect. This is particularly important with heating or power plants of a public nature or those at a university.

While at small plants expensive coal and ash-handling equipment cannot be justified, this equipment becomes a more important item in the modern large utility plant. It may amount to $5 to $6 per kw of installed capacity. Such investment is justified, however, where savings in handling costs and more efficient operation result.

The author discussed several fundamentals of design that should always be considered. Such items as slope of track hoppers to insure clearing of the coal and slope of bunker walls to prevent hanging up of coal were stressed as important. The value of a dust-tight system particularly as it makes for better and cleaner working conditions for coal and ash handlers, was emphasized by the author.

To insure a tight coal system the coal bunker should be sealed, belts should be sealed at the point of discharge as well as the discharge from the bunker to the coal scale. The use of water sprays at loading points are also important aids.

Overall safety should not be overlooked. Some desirable features include tripping devices or shut-offs and the use of interlocks. A signal light system, particularly in dark areas is highly desirable.

New Process for Producing Char

This paper recalls the bygone works in the field of low-temperature carbonization, but changed economic aspects of coal in relation to competitive fuels and certain recent developments in engineering techniques have again revived interest in the problem of power char production. Originally the object of the fluid devolatilization of bituminous coal, as carried out at The Institute of Gas Technology, was to produce a char as a substitute for low volatile Pocahontas coal used in the production of metallurgical coke. This study has recently been further extended to explore the possibilities of power char production, the results of which are described in the paper by A. D. Singh and L. J. Kane.

Kincaid Coal in a temperature range of 752–1472 F using a 50-50 mixture of coal and char were used. The coal entered a fluid char maker, or retort 6 in. diameter by 6 ft high. This retort operated at controlled temperatures and raw coal and steam were blown in continuously. The char and gaseous products pass through an electrically heated cyclone series where tar and gases were separated. The following results are of interest:

Char contained 10 per cent volatile matter and 12,180 Btu per lb as compared with 11,460 Btu per lb for raw coal. One ton of dry coal produced 1328 lb of spongy, friable char. The gas yield equalled 8300 cu ft, or 40 therms; and the tar yield 15 gallons per ton dry coal. Desulphurization of coal was effected with steam during the devolatilization process and ranged from 38.5 per cent to 76 per cent.

Char is a good pulverizable fuel and the authors stressed its usefulness for combined gas and electric systems.

Previous char-making methods were hampered because the fluid technique was not used. The authors mentioned char briquettes as a good domestic smokeless fuel. No heat balance was offered at this time except a steam requirement of 0.1 or 0.15 lb of steam per pound of coal entering the retort.

Another development under extensive study at the Institute is the flash pulverization of coal and other solid substances. The flash pulverizer system has been modified to incorporate a "cyclonizer" chamber of which the pulverizing nozzle is an integral part. By introducing hot combustion gases into the cyclonizer, char may be flash pulverized so that about 80 per cent will pass a 324-mesh screen.

Atomic Power

A session devoted to Nuclear Energy comprised two papers, one by **Prof. A. O. Nier** of the University of Minnesota, and the other by **B. R. Prentice** of the General Electric Company. Both stressed the fact that practical production of atomic power involves the solution of a number of engineering problems by the joint cooperation of the engineer and the nuclear physicist. Important among these are structural and design problems linked to control and refueling under safe conditions.

One phase of the problem is that the construction of atomic reactors requires materials whose properties are

largely unknown under present operating conditions. New materials will need to be developed so that the maximum efficiency of operation may be achieved.

Another aspect of the matter has to do with the removal of waste products from the "atomic furnace." That is, when an atomic fuel undergoes fission, elements near the middle of the atomic tadle are formed, and for each atom of U-235 that is destroyeb, two new lighter atoms are created—some of which will act as parasites in removing neutrons from the pile. At the Hanford plant, this problem was solved by removing these canned uranium slugs at regular intervals, dissolving the contents by chemical process and separating out the uranium and plutonium. The process, however, was laborious and because of the strongly radioactive character of the fission products, it had to be accomplished by remote control behind thick concrete shields. Development of continuous and less expensive methods offers a challenge to the engineer.

Another factor is choice of the "moderator"—the medium by which the fast neutrons produced in the fission process are slowed down in order to set up the chain reaction. By this means the stored atomic energy is converted into kinetic energy of the fragments formed in the fission process and this, in turn, is converted into heat which may be removed for utilization by circulating a suitable fluid around the fissionable material. By means of a heat-exchanger, steam can be produced.

Suitability of Various Slowing-Down Media

Prof. Nier discussed the possibilities of employing hydrogen, helium, lithium, beryllium, boron and carbon as slowing down media. Since the mass of the hydrogen atom is the same as that of the neutron, it possesses the best slowing-down characteristic, but its property of absorption is too great. Helium would be a good material, but since it is a gas it would be hard to obtain a high density of atoms without employing very high pressures. Lithium and boron, because they absorb neutrons so readily, are poor substances to use as slowing-down media. Beryllium and carbon are both good. The latter, because of its availability as graphite, is being used in the chain-reacting piles now operating. The need for extremely pure material was stressed.

Prof. Nier concluded by pointing out that an orderly and safe development of nuclear energy for power production would necessitate the setting up of a group of codes and standards.

Mr. Prentice was of the opinion that atomic energy would ultimately become competitive with that from other fuels. However, ten years would probably elapse before a large-scale prototype plant would be in operation, and a very much longer time before any major portion of our power demand would be supplied by nuclear power. Atomic power plants twenty years hence will probably bear little resemblance to our current conceptions. He foresaw many benefits to our industrial economy and daily life through the conversion of nuclear mass to energy. Radioactive isotopes for use in chemistry, biology and medicine can and have been made in particle accelerators. However, it is the nuclear reactor that holds promise of making them cheap enough and in sufficient quantities to broaden their use.

Discussion

In the discussion it was brought out that atomic power plants would benefit not only by use of a cheaper fuel but by the value of all the useful by-products which can be produced much more cheaply in a nuclear reactor than in a cyclotron. It was stated that in about twenty years, with the possibility of reduction in cost of equipment through engineering advances and with proper training of adequate personnel, generation of electricity by nuclear energy on a relatively large scale is anticipated.

The growth curve of this new source of power might likewise be expected to resemble that of the electricity production industry of today.

To emphasize the tremendous power of uranium, it was stated that one pound possessed theoretical energy equivalent to 11 billion kwhr but as only one-tenth of one percent of the material is converted we actually can obtain 11 million kwhr.

Report of Nominating Committee

The slate of 1947–1948 officers presented by the Nominating Committee was as follows:

President:

E. G. Bailey, vice-president of the Babcock & Wilcox Company

Regional Vice-Presidents:

Frank M. Gunby, associate of Charles T. Main, Inc., Boston, for Region 1

Paul B. Eaton, head of mechanical engineering department, Lafayette College, Easton, Pa., for Region 3

Thomas E. Purcell, general superintendent of power stations, Duquesne Light Company, Pittsburgh, for Region 5

J. Calvin Brown, Los Angeles, for Region 7

Directors-at-Large:

J. B. Armitage, vice-president of Kearney & Trecker Corp., Milwaukee, to serve 3 yr

A. L. Penniman, general superintendent of operations, Consolidated Gas, Electric Light & Power Company, Baltimore, to serve 4 yr

William M. Sheehan, vice-president of General Steel Castings Corp., Eddystone, Pa., to serve 4 yr

The above officers will be voted upon by letter ballot of the membership in October and will assume their respective duties at the close of the Annual Meeting in December. This year, instead of following the usual custom of holding the Annual Meeting in New York City, it will be held in Atlantic City, N. J., December 1 to 5 where it is believed the increased hotel facilities will prove a decided asset. However, according to present plans, the 1948 annual meeting will revert to New York.

Construction Cost Trends and Implications

By WILLIAM F. RYAN
Assistant Engineering Manager,
Stone & Webster Engineering Corp.

Excerpts from a paper before the Annual Convention of the Edison Electric Institute at Atlantic City, June 4, 1947, in which the author shows cost indices of the principal items entering into power costs over a long period. These increasing costs have thus far been largely offset by technological advances, but a period of diminishing returns has been reached. Some future expedients are suggested.

CONSTRUCTION costs are so high that we find it difficult to believe the figures. When we study the costs of a completed project, we instinctively feel that the work must have been extravagantly designed or badly managed. Estimates for projected work are even more incredible, and this applies equally whether we plan to build a power station, a schoolhouse or a new porch on an old house.

There are many factors in the present high cost level, but the price of electric power is not one of them. Power is an appreciable item in the manufacturing costs of equipment and materials, but it is one component that has not contributed to the rising commodity markets.

Fig. 1 shows the trend of some of the major items that public utilities buy. It indicates the relative cost from year to year of fuel, operating labor, electric plant and public utility bond interest, referred to the year 1914.

The cost of fuel is now about 2 $^1/_2$ times the average price prior to World War I, and nearly twice what it cost just before World War II. It is not, however, even today at its all-time peak, which was reached in 1920. The hourly cost of operating labor is now at its all-time high, $5^1/_2$ times what it was in 1914 and nearly twice what it was in 1939. A third major component in the price of power—the cost of plant—is the one with which we are here concerned. It has followed the same general trend with an index $2^1/_2$ times that of 1914 and 35 per cent over 1939.

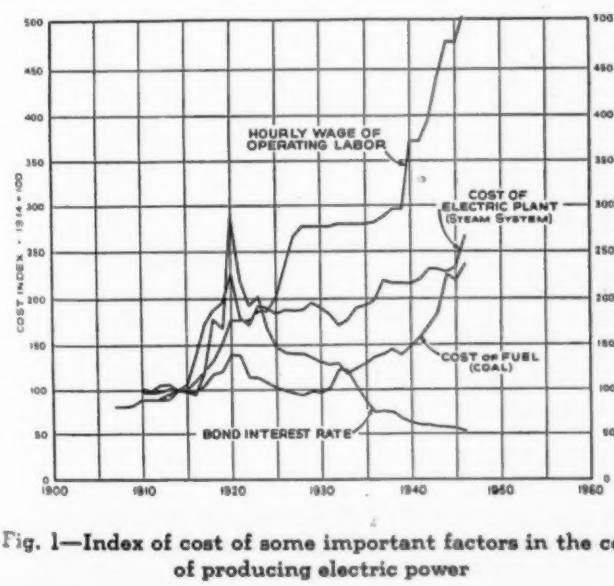


Fig. 1—Index of cost of some important factors in the cost of producing electric power

Of all the things a utility buys, the only one that has come down is the cost of money. Interest rate on utility bonds is now less than it was before either of the wars; but bond interest is not, of course, the total cost of money.

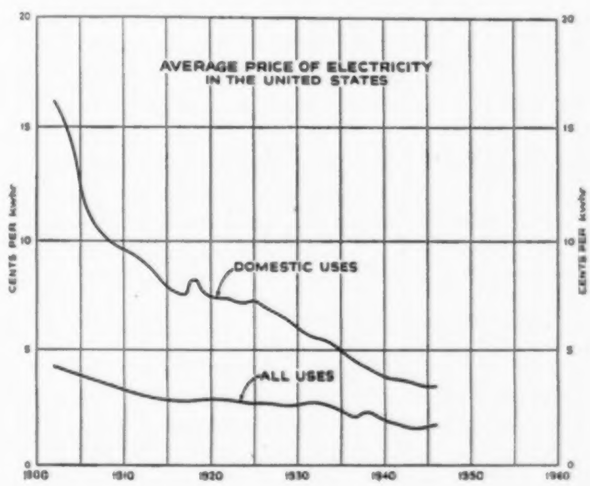


Fig. 2—Average price of electricity in the United States

Every appreciable item in production expense for electric power has risen steadily, cycle by cycle, but the industry has continued to deliver its product at lower and lower costs. While skillful marketing has played an important part in this achievement, it is largely the product of technological advances and a triumph of sound engineering. The salesmen and rate-makers who sell more and more kilowatts year by year make it possible for the engineers to install larger generating units of higher efficiency. An even more important marketing accomplishment is the mounting ratio of kilowatt-hours sold to kilowatts of demand, increasing the earning power of every dollar invested in plant and most of the dollars spent for operating labor. It is technological progress which has made it possible to double the output of kilowatt-hours per ton of coal in the last 25 years, to produce great concentrations of power from a few large

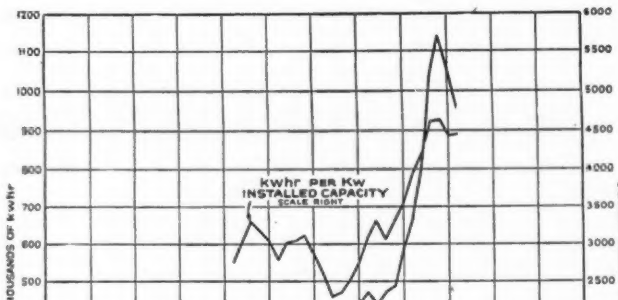


Fig. 3—Productivity of American electric power generation

units instead of a multiplicity of small ones and to interconnect vast systems so that every dollar invested in generating plant extends its potential usefulness over a wider area.

We cannot claim credit for the engineers, however, without paying tribute to management which has had the courage and the foresight to let the engineers have their head. In no other industry have engineers been given greater opportunity to pioneer and to develop their art.

Fig. 2 indicates the price the utilities get for their product. The upper curve, while spectacular, is not the whole story; the lower line is really the significant one. It represents a composite of data from Census reports, the N.E.L.A., the E.E.I. and the F.P.C.

Productivity in Electric Industry

Fig. 3 shows graphically the basic reasons why the electric industry has been able to pay more and more for all it buys, yet sells its product for less and less. Output per ton of coal burned has increased from 525 kwhr in 1915 to 1,550 kwhr in 1946. Kilowatt-hours per man-year of labor have increased from 83,000 in 1902 to more than 1,000,000 in 1943 and 1944. There has been a decline, which may or may not be ominous, since 1944. The productivity of capital investment has likewise increased. Whereas we were generating less than 3000 kwhr per kilowatt of capacity in the boom years from 1915 to 1920, we generated more than 4600 kwhr per kilowatt in 1944. There was a slight decrease in 1945 and 1946 but, at the present rate of output, we will in all probability reach an output of more than 4700 kwhr per kilowatt in 1947. The increase in productivity of capital investment is especially high for the steam production plant, for which output per kilowatt of capacity increased from 1875 in the depression year of 1932 to about 4121 in 1946.

The increase in productivity here shown has made it possible to lower rates almost continuously, but how much longer can technological progress stem this tide of rising costs? We may hope that the costs of plant, fuel and labor which comprise the cost of power have ceilings, but we know that the selling price has a floor.

Referring again to Fig. 1, the coal bought at the top of the market in 1920 was burned and replaced by cheaper coal, but the plant built that year stayed on through the subsequent depression, trying desperately to earn a fair return on its cost. Rates may be adjusted upward or downward to follow the price of fuel without excessive complaint from the consumer, but what is invested in the electric plant at the peak of the market is frozen at that level for its useful life. Rates cannot be lowered because construction costs have come down without sacrificing reasonable return on the investment already made.

Fig. 4 shows the indices of some commodities which affect the cost of an electric plant. Copper which is such an important element in the electric plant, has been cheap compared with other commodities, ever since World War I. In spite of recent price increases, it is still relatively cheap. The indices for steel and skilled labor roughly parallel the combined index for the electric plant, but those for some items of major equipment are up in the stratosphere. Largely as a result of equipment cost, that for the steam production plant is higher than this average for the combined electric plant.

Common Labor a Diminishing Factor

If common labor were shown on this comparison, it would have gone off the chart about 1938, and is now over 600, but common labor is a factor of dwindling importance in construction costs. Shop labor, no doubt, has soared somewhat in proportion to common labor and accounts in large measure for the soaring indices of equipment costs.

The index for skilled labor is not conclusive as it merely compares the hourly wage today with that of some other period. It takes no account of how much work a man does for his wages or how much premium overtime he receives. Moreover, indices of this type make no allowance for the effects of protracted periods of construction such as prevail today. The index, assuming a uniform ratio of skilled to unskilled labor, overlooks the fact that unskilled labor is gradually being crowded out of the construction industry as the skilled crafts insist on taking over more and more of the work that requires no skill. Such indices take no account of "feather bedding" and other cost burdens imposed by the

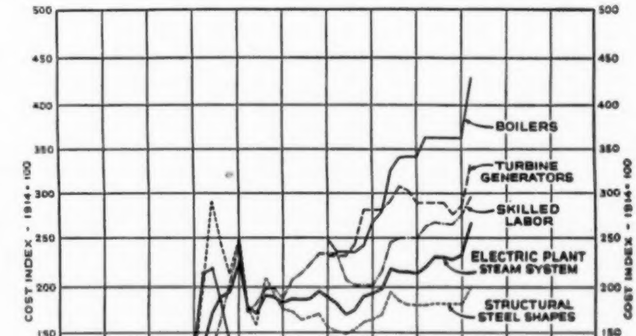


Fig. 4—Index of electric plant cost and some factors affecting it

construction crafts, so that in many respects this type of index presents a distorted picture.

It seemed desirable to construct an index which would give a more definite comparison of plant construction costs from year to year. This was not feasible for a complete electric system, but it was possible to compute an index for steam power stations. They constitute 40 per cent or more of the average cost of the electric plant in systems where power is predominantly steam generated. The data for this adjusted index were taken entirely from our own records, since we have been building power stations for nearly 60 yr and for 45 yr have complete and comparable cost records. Throughout the history of the electric light industry, for any five- or ten-year period, we have designed and constructed approximately 10 per cent of the total installed capacity in the United States. The data, therefore, seem to be entirely adequate for a reliable index.

Fig. 5 shows an index built on these data. The upper line is the conventional index for steam power stations. It is now at 372 and if corrected for efficiency of labor would exceed 400. This does not mean that it costs

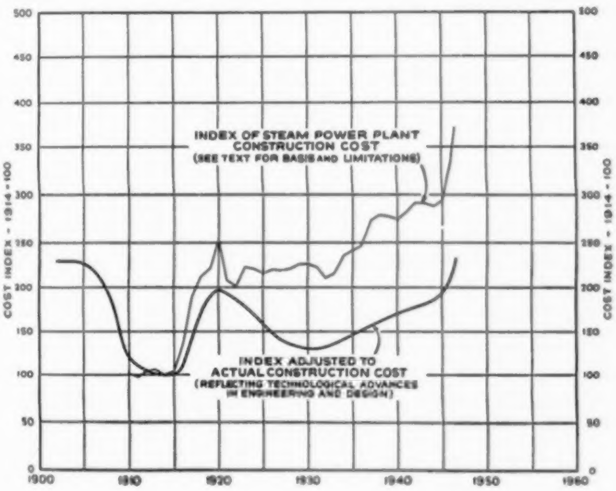


Fig. 5—Index of steam power plant construction cost, and adjusted index, reflecting technological advances

four times as much per unit of capacity to build a steam power plant now as it did in 1914. Rather it would cost four times as much to duplicate a plant designed and built that year, which of course would not be done, as larger units, higher speeds and higher rates of heat transfer would be employed. The lower line, as an index of actual construction costs, purports to reflect these technological advances.

Back in 1902 we were installing 500-kw engines with 300-hp hand-fired boilers. The cost of steam electric power stations, per unit of capacity, was even higher than it is today. Then, as turbines came into use, larger boilers were employed, fired first with overfeed then underfeed stokers, and costs came down very rapidly, reaching an all-time low just before World War I. Our adjusted index rises sharply with increased wages and prices with the outbreak of the war, but it does not reach the extreme peak of the conventional index. Technological advances were still in progress.

As the conventional index levels out on a ten-year plateau, the adjusted index falls continuously for several years. The actual cost was brought down by using still larger units, higher rates of heat transfer, and higher speeds, pulverized coal, more oil- and gas-burning plants and higher efficiency, which meant less coal-handling equipment, less circulating-water requirements and other substantial savings.

Following World War I the unadjusted index remains high, but the adjusted index falls as larger and larger units and mounting rates of heat transfer effected substantial savings in the relative cost of plant. After 1930, the trend begins to parallel the unadjusted index. The average size of units installed was still increasing, although the maximum for any individual installation was reached before that date. The subsequent savings in structural cost were of a minor nature. More equipment was installed out of doors. Cheaper building materials were used in many instances, providing functional structures rather than architectural monuments. Hydrogen cooling enabled us to get the desired generating capacity with less iron and copper. These savings barely offset increased expenditures for higher pressures and temperatures, and the effects of decreased productivity of constructing labor, so that the net gain in cost of the steam production plant has been very little since 1930.

Technological Advances Offset by Mounting Wages and Material Costs

Within the past six months, the adjusted index exceeded the peak it had established following World War I, and while it has not yet reached the levels of 1902 when we were installing 500-kw engine-driven generators it appears to be on its way to an all-time high. In any event, so far as plant cost is concerned, all the technological advances of the last 25 years have been wiped out by mounting wages and prices. If there were any indication that we are at or near a second post-war peak, there would be no cause for despair. A kilowatt of steam capacity installed in 1947 costs more than twice as much as a similar unit installed in 1914, but it is easily worth that premium. In the first place, the owner may expect to get more than 50 per cent more use out of it, due to the higher load factors now prevailing. The 1947 plant will produce 60 per cent more power for every ton of coal burned and twice as much power per man-hour of operating labor. Perhaps we can afford to pay what capacity costs today, but can we afford to pay what it will cost tomorrow?

Looking into the future, we seem to have reached the period of diminishing returns in regard to the designing engineer's ability to lower costs. Further reductions must come from some sacrifice of convenience and flexibility on the part of the operator. We do not presently aspire to larger units, but improved methods of combustion may further reduce the cost of steam generating equipment and housing. Neither do we aspire to higher generator speeds, except for the largest units. Improvements in manufacturing methods and genuine standardization may help to reduce equipment cost. New and cheaper construction materials may be developed. One virgin field for technological development is the construction industry itself. The few improvements that have been made in the art of building

have been largely vetoed by union regulations. We may even hope for improvement in the productivity of construction labor. Some day, somehow, our entire nation must learn that our boasted standard of living springs neither from high prices nor high wages, but from high production.

Substantial savings can be made at some sacrifice of convenience and flexibility by installing a single boiler for each turbine-generator and by omitting cross connections between boilers and turbines, that is, by adopting a complete unit system. We should consider whether the inconvenience of more out-of-door construction is not justified at present cost levels; after all, most of our so-called "out-of-door" plants are fairly well housed. Particularly, we should not be thrown into a panic by present fuel prices, and start a mad race for thermal efficiency at the expense of a reasonable balance between capital investment and long term production costs. Even if present fuel prices should prove permanent, let us not forget that fuel belongs in the energy component of our rate schedules, while construction costs are part of the demand charge. It is the demand charge which may cause us most concern in the years to come.

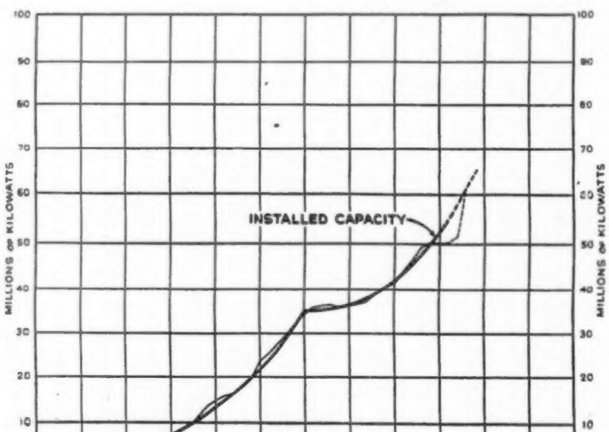


Fig. 6—Long-term trend of installed capacity for generation of electric power in the United States

It would be comforting if we could postpone investment in electric plants until we see what the future brings forth, but we have not caught up with where we were going back in 1930. Fig. 6 shows the growth of generating capacity of electric systems in the United States since the beginning of the century. The graph shows a very smooth progress from 1,200,000 kw in 1902 to 34,000,000 kw in 1930. The continuity was broken by the great depression, but again, neglecting some irregularity due to wartime construction restrictions, we seem to be making a smooth progression, passing the 50,000,000 kw mark in 1944 and plants are under construction that will bring the total to 60,000,000 kw in 1949, if present construction schedules are maintained. However, in spite of the fact that more generating equipment is on order than at any previous time in the history of the industry, we are not building as fast, comparatively, as in the 1920's. The slope of the first curve on this graph is greater than the second. Even if construction schedules are realized, the capacity available in 1949 will not provide what was regarded before the war as essential reserve, unless there is a material recession in the demand for power. Whether we like it or not, high cost or higher cost, the public utilities must keep on building.

The per capita consumption of power is 115 per cent higher in Canada than in the United States, and before World War II there were at least four European countries who outranked us in this respect, including the tiny Duchy of Luxemburg. There is every evidence that we must keep on building, now and for a long time to come if we are to keep up with demand.

The long-term outlook is equally demanding. The high labor costs which concern us in construction work and power generation are universal throughout industry. Labor-saving devices are in demand, and such devices require power. Higher earnings of the wage earner result in more completely electrified homes. Some day we shall have the "adequate housing" we are dreaming about, with all that means in domestic consumption of power.

Period of Diminishing Returns

As previously mentioned, we have reached a period of diminishing returns as to technological advances. We cannot compromise with capacity or reliability, but can cut costs appreciably at some sacrifice of convenience and flexibility. In other words, the resources of the design engineer are approaching exhaustion, and the operator must now give up some things which he has come to regard as indispensable.

Auxiliary facilities such as warehouses, shops and office space can be curtailed, or at least postponed until construction costs are stable. Outdoor equipment is inconvenient, and perhaps does not save much in percentage of plant cost, but the total potential savings in dollars are tremendous.

Unit installations may reduce flexibility, but the effect on reliability is negligible, and they save a lot of money. There is a great potential saving in *genuine* standardization. Standardization, so far, is largely a thing you read about in advertisements.

To repeat, let us not be thrown into a panic by present fuel prices and start a mad pursuit of thermal efficiency at the expense of a reasonable balance between capital investment and long-term production costs.

It may be that our proud record of constantly decreasing selling price for power has touched bottom. Actually there would be nothing disastrous in increased rates provided we can continue to sell power at a very low price in comparison to other commodities. We may not be able even to do that, if the present trends continue, but it is still too early to throw in the towel. To hold plant cost within reason, however, is a task in which the operator must cooperate with the design engineer.

In conclusion, I would express one rather forlorn hope. The technological advances discussed are all in the field of plant and equipment design. The construction industry itself has contributed little to offset higher prices and wages. We have some ideas along this line, but they are all distasteful to the construction trades.

Silica Deposits in Steam Turbines From Softening of Makeup Through Natural Zeolite

These excerpts of a paper by the author before the Seventh Annual Water Conference contain data from a number of plants showing an increase in silica content by the water in passing through a softener employing green sand. Seasonal increase of the silica content is also noted. Curves are included showing turbine performance prior to and after bypassing the green sand softeners. Blasting with fly ash proved much more effective in removing turbine deposits than washing, even over prolonged washing periods. The theory that the presence of silica in steam is selective, is confirmed.

By **F. R. Owens**, Secry.,
Cyrus Wm. Rice & Co.

USUALLY deposits of silica in steam turbines are associated with operating pressures at or in excess of 1000 psi. However, deposits consisting mostly of silica which could not be removed by washing, have been experienced at or below 600 psi. In fact, several plants within our experience have been plagued with this type of deposit in the pressure range of 400 to 600 psi.

Numerous plants in the past ten years have installed new boilers and turbines to operate at 400 to 600 psi and retained their old water softeners. In many cases these were base-exchange units charged with green sand. Also, completely new installations within this pressure range have been made with green sand as the base-exchange mineral in the softener. A number of such installations have encountered deposits, consisting largely of silica, on the turbine buckets, diaphragms and nozzles, which materially impaired turbine capacities and operation after several weeks' service.

TABLE I

Source	A	B	C
Silica (SiO_2)	93.89	88.10	88.01
Iron (Fe_2O_3)	2.56	6.00	4.20
Sulphate (SO_4)	1.40	0.42	3.46
Chloride (Cl)	.37	1.27	0.96
Hydroxide (OH)	none	none	none
Carbonate (CO_3)	none	0.42	none
Phosphate (P_2O_5)	none	0.49	0.94
Calcium (CaO)	0.29	none	0.12
Magnesium (MgO)	0.06	none	none
Sodium (Na_2O)	1.01	1.65	1.42

The data in Table 1 reveal the chemical characteristics of such deposits from three different plants, the samples being taken from the extraction stage in each case. Invariably, the heaviest deposits were at this stage in the turbines. The pressures for plants A, B and C were 420, 600 and 600 psi, respectively. The extraction pressures were 80, 130 and 130; and the steam temperatures 465, 350 and 400 F, respectively.

It was possible in some instances to restore turbine capacity by washing at frequent intervals; but in most cases it was necessary to clean the machines by fly-ash blasting when the chemical characteristics of the deposit were as shown in Table 1. X-ray diffraction revealed this to be quartz.

TABLE II

A — River Water — after filtration.

	Average Analysis, p.p.m. Entering Softener	Leaving Softener
Dissolved solids	29.5	36.6
M.O. alkalinity ($CaCO_3$)	11.3	12.1
Calcium (CaO)	9.7	1.5
Magnesium (MgO)	1.2	0.7
Chloride (Cl)	9.4	11.8
Sulphate (SO_4)	10.8	13.6
Silica (SiO_2)	5.78	7.74
R_2O_3 ($Fe_2O_3+Al_2O_3$)	0.9	1.0
pH	7.95	8.0

B — Well Water — after filtration.

	Average Analysis, p.p.m. Entering Softener	Leaving Softener
Dissolved solids	218.4	225.0
M.O. alkalinity ($CaCO_3$)	55.0	60.0
Calcium (CaO)	13.5	2.6
Magnesium (MgO)	10.0	1.7
Chloride (Cl)	23.0	25.5
Sulphate (SO_4)	94.0	94.8
Silica (SiO_2)	6.33	8.61
R_2O_3 ($Fe_2O_3+Al_2O_3$)	3.7	3.3
pH	8.6	8.6

C — Lake Water — after filtration.

	Average Analysis Entering Softener	Leaving Softener
Dissolved solids	185.0	192.0
M.O. alkalinity ($CaCO_3$)	58.0	62.0
Calcium (CaO)	31.7	2.8
Magnesium (MgO)	11.9	1.4
Chloride (Cl)	17.0	21.0
Sulphate (SO_4)	84.0	88.8
Silica (SiO_2)	3.30	5.15
R_2O_3 ($Fe_2O_3+Al_2O_3$)	2.6	2.5
pH	7.6	7.7

D — City Water — mountain reservoirs.

	Average Analysis Entering Softener	Leaving Softener
Dissolved solids	31.0	36.0
M.O. alkalinity ($CaCO_3$)	8.5	8.9
Calcium (CaO)	5.9	1.0
Magnesium (MgO)	3.0	0.7
Chloride (Cl)	6.1	7.1
Sulphate (SO_4)	19.8	20.5
Silica (SiO_2)	3.04	4.20
R_2O_3 ($Fe_2O_3+Al_2O_3$)	1.6	1.7
pH	6.4	6.6

Resorting to changes in chemical environment, such as reduction of hydrogen ion concentration, reduction in dissolved solids within practical limits for the particular plant and the use of magnesium salts in the boiler water, results in very little relief. The elimination of the green sand invariably effected a material improvement in turbine operation and performance, due to a reduction of silica in the steam.

It has been possible in some cases, after eliminating the green sand, to operate for two years with the machines continuing to carry up to rated capacity.

TABLE III

City Water — mountain reservoirs.

	Average Analysis Entering Softener	Average Analysis Leaving Softener
Dissolved solids	31.0	36.0
M.O. alkalinity ($CaCO_3$)	8.5	8.9
Calcium (CaO)	5.9	1.0
Magnesium (MgO)	3.0	0.7
Chloride (Cl)	6.1	7.1
Sulphate (SO_4)	19.8	20.5
Silica (SiO_2)	3.04	4.20
R_2O_3 ($Fe_2O_3+Al_2O_3$)	1.6	1.7
pH	6.4	6.6

We have noted during the past twenty years that a large percentage of the water supplies softened by means of green sand show an increase in silica after the softeners. This is indicated in Table 2 which shows the average chemical characteristics before and after the softeners for four different types of water supply, namely, river water after filtration, well water after filtration, lake water after filtration and city water from mountain reservoirs. While these do not cover completely the entire range of industrial waters, they are sufficient to show that silica is dissolved by most water supplies in passing through a green sand bed. It must be recognized, however, that in many instances an increase in silica is not experienced.

TABLE IV

Average analysis boiler blowdown water. p.p.m.

	Twelve Months Period Prior to By-passing Softener	Twelve Months Period After By-passing Softener
Pht. alkalinity ($CaCO_3$)	94.0	108.0
M.O. alkalinity ($CaCO_3$)	188.0	204.0
Phosphate (PO_4)	35.0	28.5
Chloride (Cl)	74.9	59.0
Sulphate (SO_4)	221.0	260.0
Silica (SiO_2)	29.3	30.7
Sulphite (SO_3)	11.8	13.1
Dissolved solids	621.0	647.0
pH	10.60	10.65

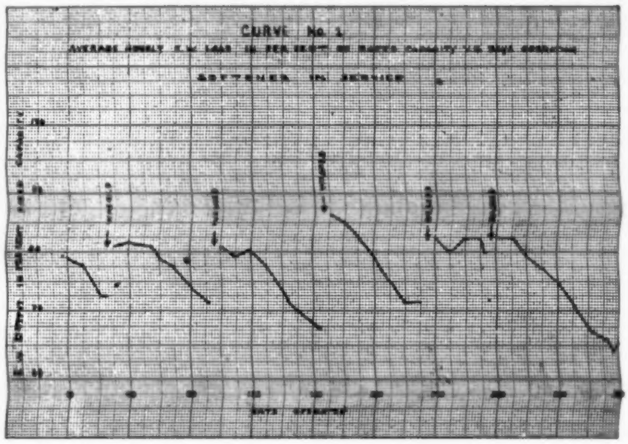
TABLE V

Steam Quality — Superheated

	Twelve Months Period Prior to By-passing Softener			Twelve Months Period After By-passing Softener		
Specific conductance Micromhos per cm.	0.51 to 0.73			0.48 to 0.74		
	max.	min.	avg.	max.	min.	avg.
Silica (SiO_2) p.p.m.	0.315	0.126	0.245	0.130	0.074	0.084

It was apparent from the complete data[1] that the silica increase is a function of temperature, as revealed by seasonal analyses. Coincident therewith is also the effect of increased growths of organic organisms and the necessity for more frequent regenerations during the summer months. Also, there is the effect of increased flow rates encountered during certain seasons.

[1] In the original paper Tables 2 and 3 also contain the monthly analyses but space here permits reproducing only the average figures—Editor.



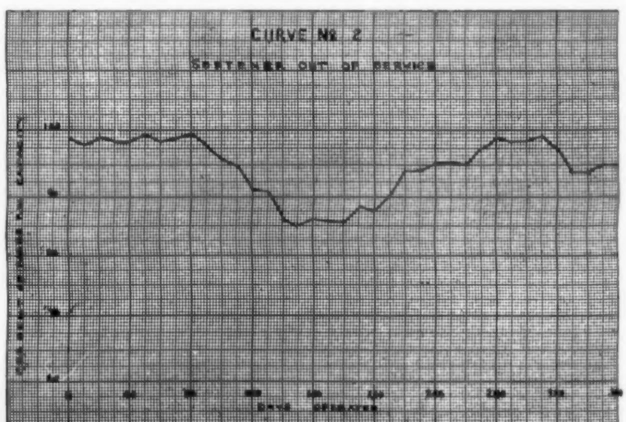
The writer agrees with the general opinion that the loss of silica from green sand increases as the hydroxyl ions (pH scale) increase, but our studies indicate that a greater tolerance is permissible than that which is generally accepted as safe limits. It is further apparent that, in general, the solution of silica increases as the total ion concentration in a water supply increases.

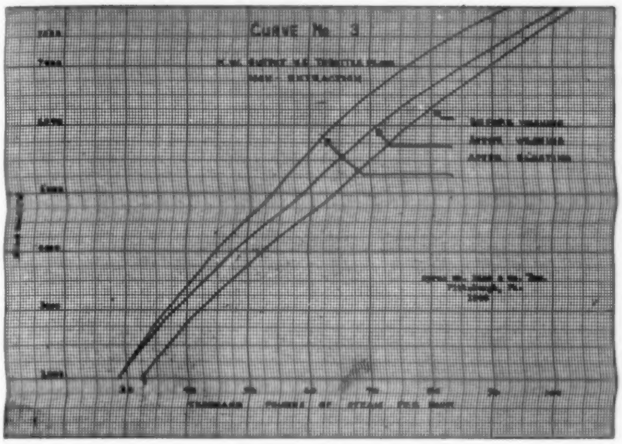
Table 3 gives average analyses, before and after the green sand softener in which steam at 585 psi, 650 F is supplied to the throttles of impulse turbines, with extraction at 130 psi, 350 F. City water from mountain reservoirs was the source of supply. These data reveal the usual increase in silica as a result of such softening.

Some authorities may consider the pH of the city water entering the softener too low for natural green sand. Although the resulting data are not shown, we did operate for an extended period while holding the pH of the water entering the softener between 7.0 and 7.2 and very little difference was found in the silica content of the softener effluent over that shown in the table.

Table 4 shows the average analysis of the boiler water and Table 5 that of the steam for the twelve months prior to elimination of the green sand and the twelve months following the bypassing of the softener.

The silica concentration in the boiler water is, in most cases, found to be less after eliminating green sand softening, but this plant was an exception. It was logically decided to maintain the same percentage of blowdowns after discontinuing the softener. The fact that the silica concentration remained about the same appears as evidence



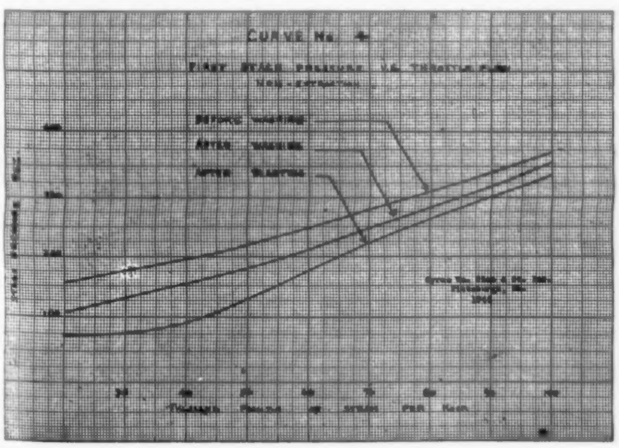


that the silica removed by the water from the green sand was carried in its entirety by the steam. There has been no increase in the amount of deposits in the boilers and deposits in the superheaters have not occurred. There is, of course, the possibility that the amount of suspended silica increased, but this is refuted by daily tests.

Curves 1 and 2 represent a study in turbine performance for the twelve months prior to bypassing the green sand softeners and for the twelve months' period after the softeners were removed from service. During the period covered by Curve 1, the hydrogen ion concentration was reduced, magnesium salts were used and dissolved solids and silica were reduced in the boiler water by increased blowdowns.

Turbine washes of short duration were resorted to at frequent intervals. The washes indicated by the curve were for periods of 18 and 48 hr. The short washes of 4 to 10 hr were found only slightly beneficial. A wash of 18 hr or longer always improved the turbine performance, but even the 48-hr washings failed to restore the machines to a condition where performance approximated the manufacturer's curves.

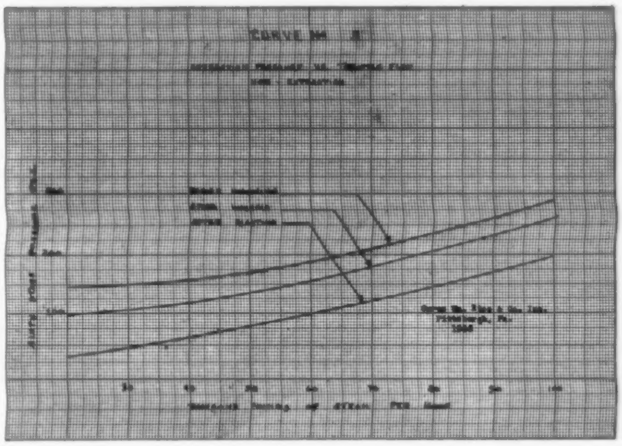
The washing was accomplished by unloading the turbine and then dropping the speed to 15 to 25 per cent of normal. The steam temperature was then reduced according to the manufacturer's instructions until temperatures below saturation at the throttle were reached. Feedwater was mixed with superheated steam in the bypass installed for this purpose ahead of the stop valve. Caustic soda was not used because of the valve construction.



The ineffectiveness of even extended washing, as compared with fly-ash blasting, to remove a predominantly silica deposit, is reflected in Curves 3, 4 and 5. The turbine performance after blasting is in practical agreement with the manufacturer's curves. After 16 months' operation turbine performance and operation continue satisfactory.

It does not appear feasible to suggest a fixed tolerance for silica concentration in the steam and boiler water to obviate excessive silica deposits in turbines for a given steam pressure and temperature. Preferably, such tolerances should be determined for each installation. Also, it is desirable to determine the silica concentration of the *saturated steam.*

The ratio of silica in the steam to that of the boiler water at the plant under discussion, is considerably higher than the ratio of dissolved solids in the steam (basis specific conductance) and those of the boiler water. This is in accord with Straub[2] and Grabowski[2] that the silica is present in the steam as a result of selective entrainment.



Both Jakob[3] and Wahl[4] sought to show that silicates conform to Werner's theory of complex structure. The investigations of Goldschmidt[5] were more successful through the preparation of compounds isomorphic with silicates. The studies of Bragg[6] by means of X-ray analyses improved the situation in the silicate group considerably. It is important to note that as a result of Bragg's research it is not possible, with most silicates, to think in terms of the isolated molecule. In other words, the usual formulae cannot give an exact representation of the structure. Unfortunately, our present knowledge of the vapor phase of silica in water vapor is so meager that its molecular structure at best can only be hypothetical. The molecular structure may be silicic acid, either H_2SiO_3 or H_4SiO_4, as Straub and Grabowski propose. Again, it may be silica (SiO_2), as suggested by Imhoff.[2] We suggest that the silica vaporizes from aqueous solutions of alkaline silicates in various degrees of hydration, thusly—$SiO_2 . X H_2O$.

[2] "Silica Deposition in Steam Turbines," Trans., A.S.M.E., July 1945.
[3] Helv. Chim. acta. 1920, 3 . 669.
[4] Z. Kryst, 1927, 66 . 33, 173.
[5] Geochemische Vertielungsgesetze, VIII, Oslo, 1926.
[6] The Structure of Silicates, 2nd ed., Leipzig, 1932.

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Drainer Equalizing Connection Improves Heater Performance

If any part of the feedwater heating and conditioning system fails to operate exactly in the prescribed manner it disturbs the heat balance and may have far-reaching effects on the efficiency of the plant as a whole. A case of this kind was recently discovered in which water temperature leaving a closed heater designed for an outlet temperature of 310 F, when supplied with extraction steam at 75 psi, began to gradually fall off in performance until it got down to 270 F. The heater was taken out of service and carefully inspected and found to be clean.

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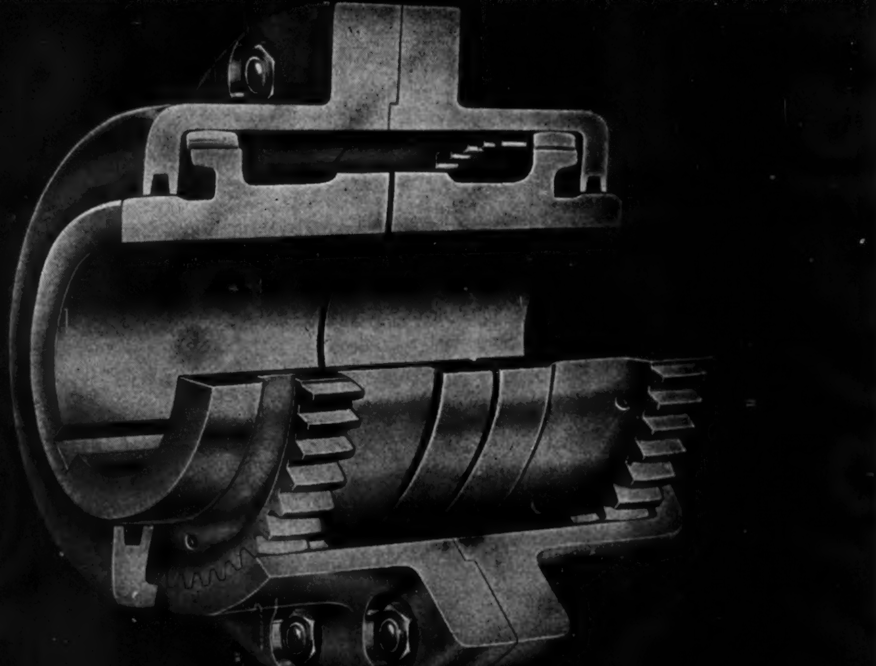

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FLEXIBLE COUPLINGS

POOLE FOUNDRY & MACHINE COMPANY WOODBERRY, BALTIMORE, MD.

X-Ray Protection Being Studied at Bureau of Standards

SCIENTISTS at the National Bureau of Standards are engaged in an extensive program for determining the effectiveness of concrete as a protective barrier against million-volt wide-beam X-rays, whose use is increasing in both medicine and industry. At the present time, exact wall thicknesses and most desirable types of construction necessary for maximum short-wave-length X-ray protection are not definitely known. One of the basic aims of the new project is to collect data from which the highest degree of protection with the lowest possible cost of installation can be calculated.

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Institutions using million-volt equipment have been seriously concerned with this phenomena and in order to assure a wide margin of safety have constructed walls of exceptional thickness. Field attempts to make measurements establishing optimum thicknesses and construction characteristics involve so many variables that the entire project, except for final testing, must be carried out in the laboratory, where the variables affecting radiation hazards can be simulated, controlled, and analyzed.

Industrial X-rays are used in three ways for metal examination. Radiographs are obtained by directing beams of X-rays through a metal object and recording the shadow lines on photographic plates. Many examinations of small parts are made by a fluoroscopic screen. A relatively new technique, X-ray diffraction, is a method for studying crystalline structure, where the X-rays are diffracted by the crystals within the metal and are recorded photographically or by means of a Geiger counter.

To determine protection standards, a $1^1/_2$ million-volt X-ray machine in the Bureau's laboratories has been converted so that it will produce beams of varying widths. It is mounted so that it can be directed downward into a "radiation pit" about six feet square and twenty feet below the target of the X-ray tube. Special instruments, designed to explore the strength of the radiation in the pit, can be shifted to various positions by remote control. Both the control and the X-ray reading equipment are operated from a central control room surrounded by eighteen inches of concrete and located seventy-five feet from the radiation pit.

During the investigations, test slabs of concrete each weighing two and one-half tons and measuring six inches in thickness are used. These slabs, when placed over the mouth of the pit one at a time, enable investigators to vary the protective barrier from six inches to five feet in thickness. Since space and weight are of critical importance in many installations, arrangements have also been made for producing "sandwiches" of lead and concrete in alternate layers. At present, the best proportions between these two materials are unknown.

Studies of radiation hazards have been carried on continuously at the National Bureau of Standards since 1913. At that time the early type of gas-filled X-ray tube was used. Though voltages were low, long exposures may have been responsible for the many cases of serious burns on record for that period. About the time of the first war, the new high-vacuum Coolidge X-ray tube came into use, operating at higher voltages, with radiations of correspondingly greater powers of penetration. Exposure times were reduced, eliminating some of the hazard to the operator. But accompanying this was the increased penetration of the X-ray due to higher voltages and the greatly extended use of X-rays with the increased versatility of the equipment. Tubes for diagnostic processes were built for operation around 90,000 volts. Soon after this came the introduction of the superficial therapy X-ray tube operating at potentials of 140,000 volts.

In the early 20's there appeared the first tubes for deep therapy use operating at voltages of 200,000 and 250,000. Here the hazard was greatly increased as was the problem of protection. In 1927, urged and supported by all of the radiological societies and the American Medical Association, the Bureau undertook a broad expansion of its activities in the X-ray field. These were centered about two major problems: (1) that of measuring X-ray dosage and (2) the study of X-ray protection hazards and formulation of principles to be used in their elimination.

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One of the Bureau's first problems was to study the ways and means for improving the protection in the immediate vicinity of the X-ray tubes in such a way as to reduce the protection necessary in the walls. As a result of these early studies, it was realized that a relatively small weight of lead could be placed closely around the X-ray tube allowing the X-rays to escape only in the direction in which they would be utilized. By doing this, lead protection in the remaining walls of the room could be reduced fifty to seventy-five per cent except for the small portion of the walls or floors in the path of the main beam. This meant immense savings in the initial cost of X-ray installations.

At about the same time, studies were undertaken to determine the efficiency of such auxiliary protective devices as lead aprons, lead rubber gloves, lead glass windows, and wall plasters made of material loaded with lead or barium. Some of these devices were found to be effective while others were not. For example, lead glass goggles for the protection of the eyes were found to offer little or no protection. In fact, they proved to be more of a hazard than a protection because they gave the user a false sense of security.

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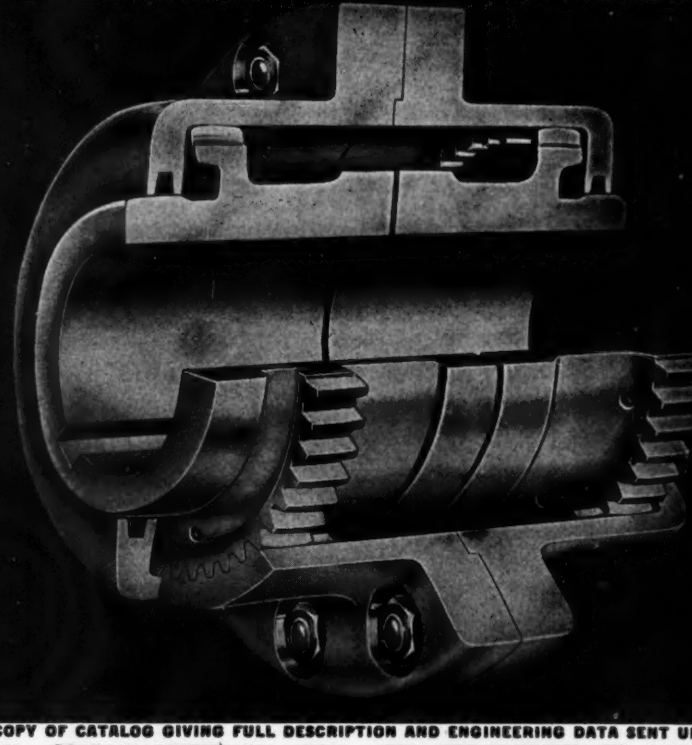

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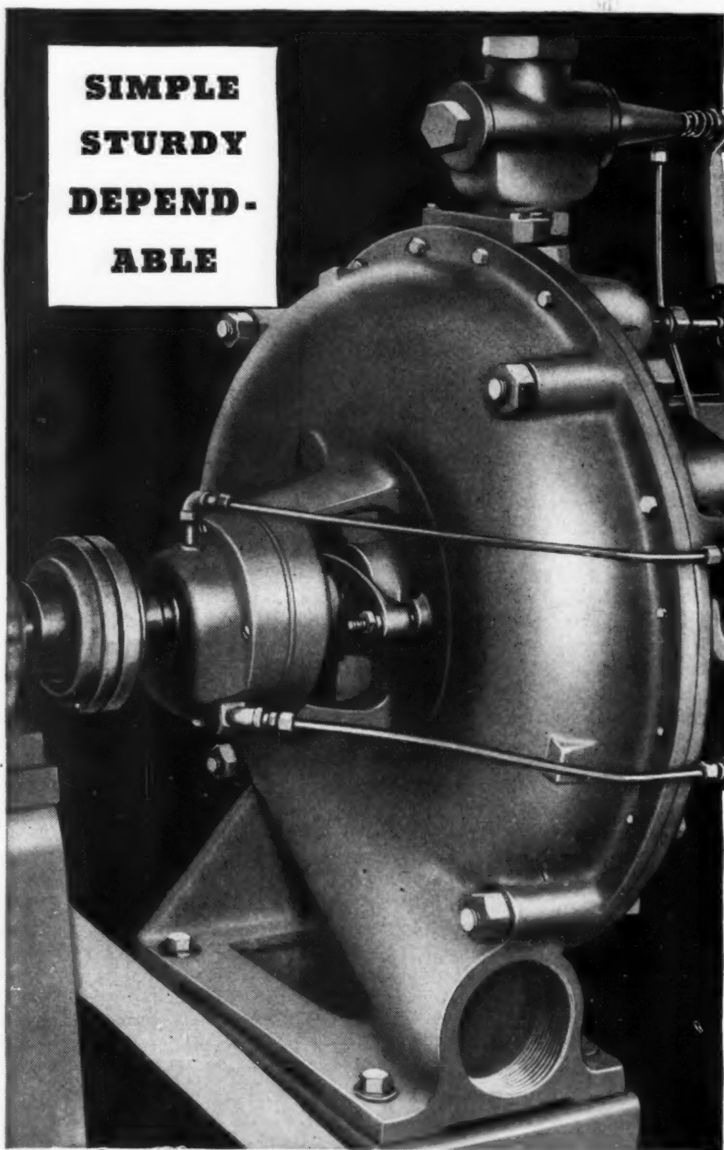

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with requirements, additional substantial economies in protection could be introduced. Studies were made to determine exactly how much protection would be required in a wall or floor that was not subjected to the primary X-ray beam, but was only subjected to the rays which were scattered from the material under irradiation.

By the time that X-ray voltages had gone up to one and two million volts, the protection problem again became critical. Studies were undertaken along the same line as for 400,000 volts, and it was determined that in most cases all secondary X-rays could be satisfactorily stopped by an ordinary reinforced concrete wall, varying in thickness from 8 to 12 inches. To cut off the direct beam would require from 12 to 18 in. of concrete, but it was usually possible to minimize this extra thickness of protective concrete by restricting the direction of the X-ray beam.

Laboratory Exploring Protection up to 300 Million Volts

Early Bureau findings have been incorporated in the construction of the present high voltage laboratory, which has X-ray tubes operating at $1^1/_2$ million volts. These plans of course had to be made in advance, but after the building was completed careful radiation hazard surveys have shown that direct applications of the protection principles for concrete have provided a wide margin of safety.

With the advent of the betatron operating at from 50 million to 300 million volts, scientists are confronted with a new series of X-ray problems. While protection from the direct beam of X-rays at 50 million volts is very important, there are other simplifying factors. For example, as science goes to higher and higher voltages in the production of X-rays, the rays themselves tend more and more to merge in a single direction from the target. Thus the X-ray beam emerging from a 50 million-volt betatron covers the very small angle of only 6 or 8 deg. For this beam alone, very great thicknesses of concrete may be required. On the other hand, X-rays which are scattered sideways out of this beam are of very much less penetrating character, and as a consequence it may be found that the protection problem to the side of the beam may be seriously different from that at one or two million volts.

These problems, however, are all uncertain at the present time and it is the responsibility of the National Bureau of Standards to set up the necessary experimental arrangements to properly evaluate them. Again, a solution must be found which is safe and yet provides the maximum economy, since the cost of protection alone in a 50 million-volt installation may represent half to three-quarters of the total cost.

Presumably when these investigations have been completed the Bureau will issue a set of rules embodying its findings, which will be of assistance to both industrial and medical users of high voltage x-ray equipment.

Hopes Exceeded in Mine Gasification Tests

Economic studies to assess cost factors and gage the industrial significance of burning unmined coal to produce gas were recommended to the U. S. Bureau of Mines following a conference on June 11 of a group of engineers, scientists, coal industry men and representatives of government services, at which time results were reported on the recent joint experiment of the Alabama Power Company and the Bureau at Gorgas.

Here, as previously announced in these columns, a block of coal was isolated and set on fire with incendiary bombs under controlled conditions. The experiment lasted 50 days and demonstrated that, even under bad roof conditions, combustion could be maintained underground and the coal burned out clean without wastage.

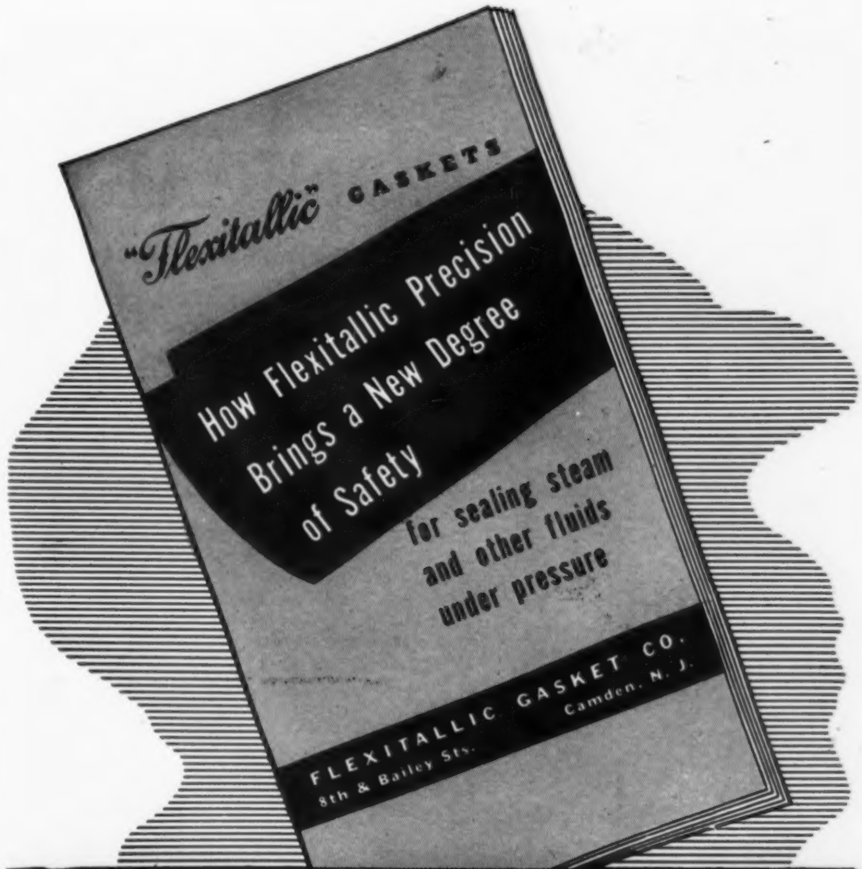
According to M. H. Fies, manager of coal operations of the Alabama Power Company, the roof action is the crux of the problem. The shallowness of the 30-ft overburden resulted in leaks and burnouts and thus limited the air input to around 1400 cu ft per min at 1.5 psi. This prevented the desired temperature being attained during air blasting, with the result that the heat content of the gas during the air-blasting operations was held to a range of from 50 to 100 Btu per cu ft. However, a gas of 150 Btu heating value was produced and gas analyses corresponded to that which would be produced at 1250 F at equilibrium conditions with a limited supply of only 200 cu ft per min of oxygen, and 291 Btu when steam only was used.

Gasification May Salvage Worked-Out Seams

Coal mining in Alabama is classed as "high cost" because the seams are thin or with many partings of non-combustible material which requires costly preparation for removal; hence any process which can reduce such cost is desirable. Even in low-cost states, coal seams now regarded as worthless, would become useful for underground gasification.

Commenting on the test at Gorgas, the Bituminous Coal Institute states that, "recognizing this as an experiment and that further research is necessary, if successive experimentation indicates underground gasification of coal to be economically feasible under proper conditions, it could develop a great potential significance. The resultant synthesis gas "could be converted by the chemical engineer into a high-heat-value gas for firing industrial boilers and in arid regions electric power might be generated by using the gas in gas turbines."

At the June 11 conference, Dr. A. C. Fieldner, of the Bureau of Mines, reviewed the history of underground coal gasification in which the Russians have pioneered; although it was an Englishman, Sir William Siemens, who first suggested in 1868 that slack and waste coal in mines be gasified. In 1938, following five years of small-scale experimentation, the Russians built a series of industrial stations for underground gasification in the Donetz coal basin, the Lower Moscow coal basin



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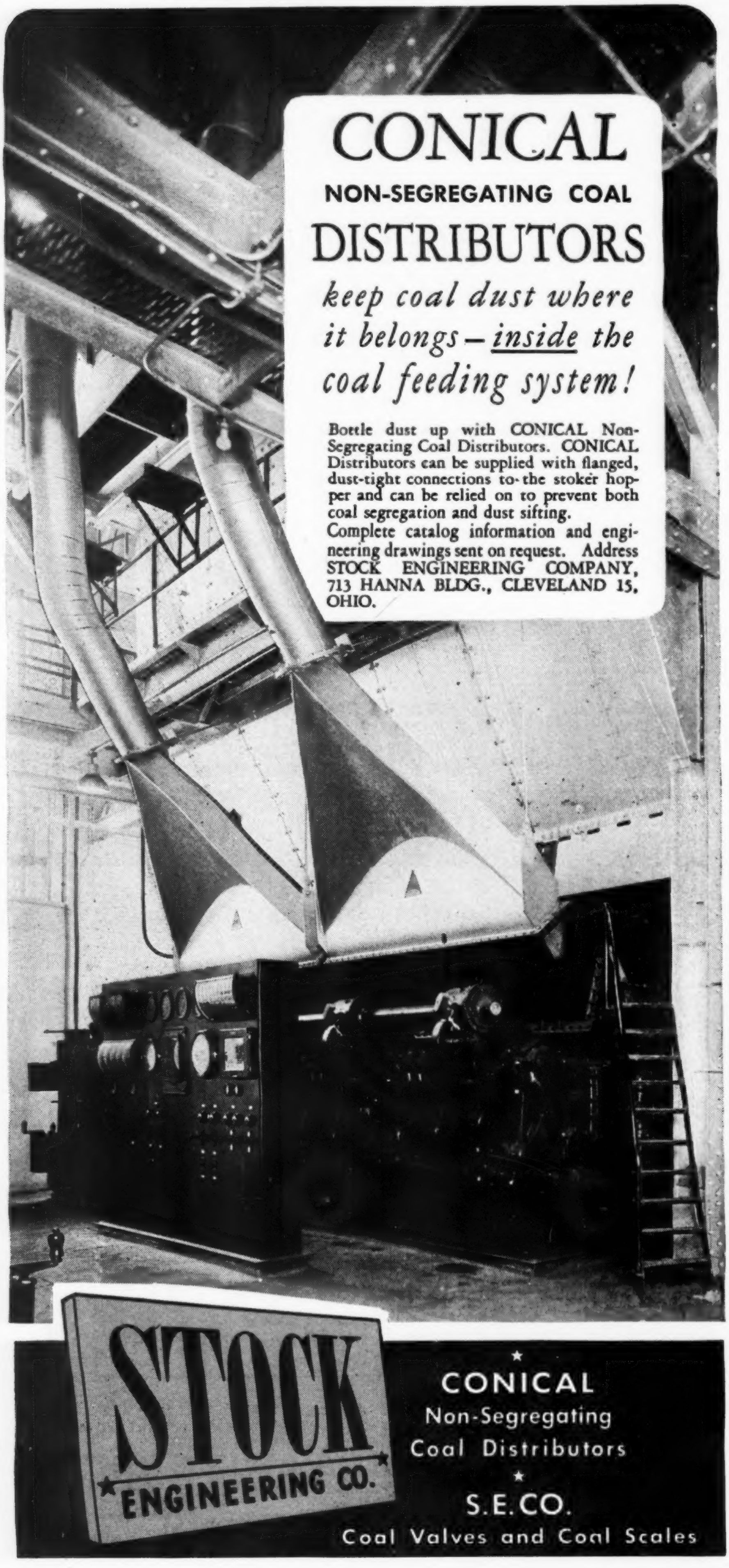

and in eastern Russia, making use of the gas for power, chemical works and domestic purposes. The largest of these was designed to produce 14 million cubic feet of gas per hour, equivalent to half a million tons of coal per year, but little information has been made available concerning its operation. The U. S. Bureau of Mines has made several attempts to arrange for American engineers to study these operations in Russia, but has not been successful to date.

Dr. L. C. McCabe, also of the Bureau of Mines, told of recent conferences with Belgian scientists at Brussels on underground coal gasification. The Belgians, he said, were unwilling to release much information at this time, because of pending patents; but they held that roof conditions and the use of a pulsating air current are keys to success.

If successful and economical underground coal gasification can be achieved, its importance is emphasized by the fact that liquid and gaseous fuels and oil shale, according to present estimates, make up only 1.2 per cent of the mineral-fuel reserves of the United States; whereas coal and lignite account for 98.8 per cent of the total.

Use of Steam for Air Conditioning

Load factors of the twelve largest district steam-heating companies range from 22 to 39 per cent which is substantially below those of electric utilities. Since the major portion of the revenues of steam companies is derived from steam heating, one of the most promising means of building up summer load, with accompanying increase in load factor and consequent increased revenues, lies in the field of air conditioning. That is, use of steam for comfort cooling represents an ideal incremental load where the customer uses steam service for heating during the colder months, and little or no additional capital investment on the part of the steam utility is required for such summer load which extends partly into the spring and fall.

These points were emphasized in a paper by Boris Dmitrief at the recent Annual Meeting of the National District Heating Association, who listed 32 such installations in stores, office buildings, banks, etc., as supplied by the New York Steam Corporation. Of these ten were steam-turbine driven and the others steam-jet systems. It is also probable that the new United Nations Headquarters, where there is little question as to the use of steam service for heating, may use steam as the source of some 6000 tons of refrigerating capacity required for air conditioning.

Mr. Dmitrief pointed out that steam-jet refrigeration can be utilized economically where the capacity is 200 tons and over, and steam is available at 100 psi or higher; where the water cost is low and cooling tower space is available; and if there is a high sensible heat load factor.

Use of steam engines to drive reciprocating refrigeration compressors can often still be justified in large plants where there is considerable demand for low-pressure exhaust; and in smaller capacities the con-

densing uniflow engine will have a lower water rate than equivalent turbine drive. However, the field of the steam engine in air conditioning is limited, principally because of the higher cost compared with that of a motor-driven reciprocating compressor.

The present trend in large air conditioning installations (250 tons and over) is toward the turbine-driven centrifugal compressor which is reliable, compact and economical to operate. In selecting the turbine the smaller cooling tower made possible by the lower water rate of a more efficient machine should not be overlooked.

E.J.C. to Advise State Dept.

The Engineers Joint Council, acting on a request of the State Department, has established a five-man advisory committee with a twofold purpose: to serve as a consultative and advisory group to the State Department as and when requested; and in a similar way to serve the Engineers Joint Council representative on the U. S. National Commission on UNESCO, who is shortly to be named.

The newly authorized group is called a "Consultative Committee to the Committee on International Relations of E.J.C." It is composed of one member of each of the constituent societies, as follows:

E. M. Hastings, President of the American Society of Civil Engineers.

Clyde Williams, President of the American Institute of Mining and Metallurgical Engineers.

D. Robert Yarnall, Past President of The American Society of Mechanical Engineers.

W. E. Wickenden, Past President of the American Institute of Electrical Engineers.

J. G. Vail, Past President of the American Institute of Chemical Engineers.

Power Figures for May Show Increase

Reports on electric utility power for May have just been made available by the Federal Power Commission. They show a total output of 20,776,294,000 kw-hr which was 17.5 per cent over that of May 1946 and represented a new high for the month. Of this total 64.4 per cent was produced by fuel burning plants and 35.6 per cent by water power.

For the twelve months ending May 31, 1947 the total electric utility output was 239,358,658,000 kw-hr, an increase of 11.8 per cent over the year ending May 31, 1946.

Coal burned during May 1947 amounted to 6,682,562 tons which was 35.4 per cent over that consumed in the corresponding month of last year. However, this increase was accompanied by a decrease of 7 per cent in the oil consumed. Gas consumption during the same month was 10.9 per cent above that of the year previous.

Stocks of coal on hand as of June 1, 1947 were equivalent to an average of 79 days' supply at the May rate of consumption, and stocks of fuel oil to 55 days' supply.

Industrial production of electricity, including generation by railway power plants amounted to 4,232,786,000 kw-hr for May 1947 which was an increase of 17.2 per cent over that of the same month last year.

The installed capacity of generating plants in utility service in the United States on May 31, 1947 was 50,538,532 kw, according to preliminary figures. This was an increase of 80,809 kw over the preceding month. The total industrial capacity was 12,775,035 kw as of the same date, making the combined utility and industrial installed capacity over 63 million kilowatts.

Data from the same source showed operating revenues of the privately-owned class A and B electric utilities for May 1947 to have been $294,795,000 as compared with $261,339,000 for the same month last year. This was an increase of 12.8 per cent. However, operating expenses and taxes increased 16.4 per cent during the year.

Personals

Prof. C. R. Soderberg has been appointed head of the department of mechanical engineering at Massachusetts Institute of Technology. He succeeds Dr. J. C. Hunsaker who will devote his entire attention to direction of the Institute's rapidly expanding program of research and instruction in aeronautical engineering.

H. W. Wimberly has been elected vice chairman of the Federal Power Commission, succeeding Richard Sachse who recently resigned from the Commission.

Alexander Matiuk, formerly power plant project engineer with Ebasco Services, Inc., has joined the staff of Douglas M. McBean, consulting engineer of Rochester, N. Y.

R. C. Allen, formerly in charge of the Allis-Chalmers steam turbine department, has been appointed manager and chief engineer of that company's new turbo-power department which will embrace the whole field of turbo power, including gas turbines.

Lawrence B. Schmitt has been named to the staff of Battelle Memorial Institute, Columbia, O., where he will be associated with the division of fuels technology.

Edward T. Moore and **Charles B. Cochran** have recently joined the staff of the Peter F. Loftus Corp., consulting engineers of Pittsburgh.

T. K. Glennan has been appointed president of Case Institute of Technology, Cleveland, O., succeeding **Dr. W. E. Wickenden** who will retire on September first after 18 years' service. Mr. Glennan has been an executive of Ansco Division of General Aniline & Film Corp. and during the war was director of the U. S. Navy Underwater Sound Laboratory.

N. E. Funk, vice president in charge of engineering of the Philadelphia Electric Company, has been advanced to the position of executive vice president. He succeeds H. B. Bryans who was named president to succeed H. P. Liversidge who, in turn, becomes chairman of the board.

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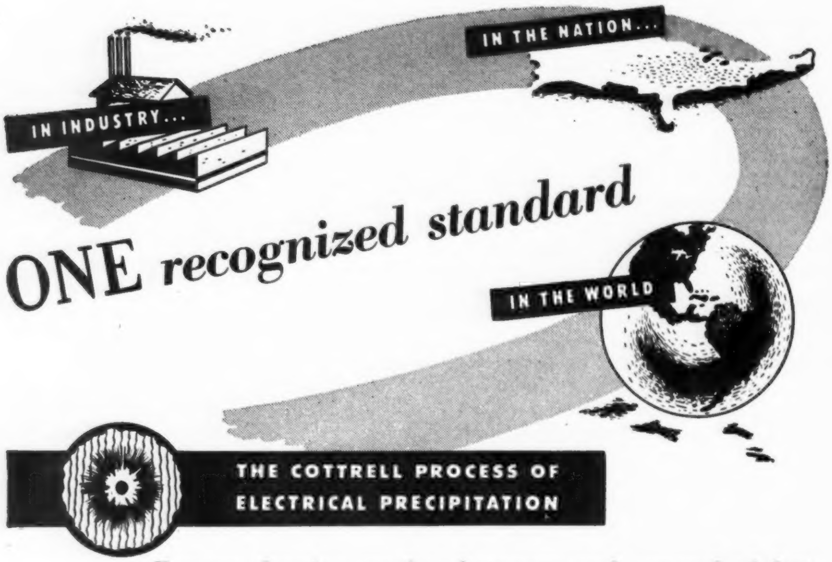

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Engineers Needed by War Department for Overseas Service in Various Capacities

The War Department has need for trained engineering personnel at overseas installations in connection with such services as water supply and sewage, electrical supply, refrigeration, air conditioning and heating, as well as maintenance of buildings, grounds, highways, etc. It has therefore asked us to make the following announcement with the thought that some COMBUSTION readers may be interested either personally or in passing the information along to some of their friends who may be receptive to the opportunity offered.

"Civil, sanitary, electrical, mechanical, refrigeration and air conditioning engineers are needed to fill overseas positions with the U. S. Army Engineers. Positions are available at Guam, Philippine Islands, Okinawa, Japan, Korea and in the Caribbean Areas. Salaries range from $3306 to $8875 per annum. Housing for dependents is not generally available.

"Applications should be made to Civilian Personnel Branch, Office of the Chief of Engineers, Building T-7, Gravelly Point, Virginia. Applications should include completed Form 57, U.S. Civil Service Commission, in duplicate, copies of which can be obtained at your local post office."

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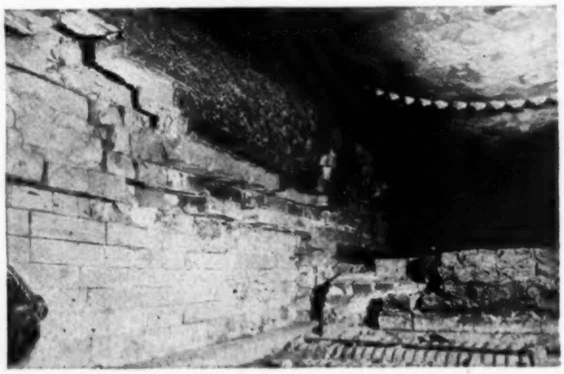
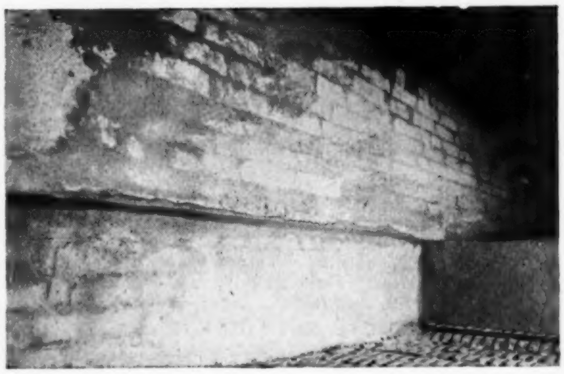


Here is a typical large boiler refractory wall in a bad state of repair. Note how the refractory cement has loosened at the joints and the firebrick fallen out.



The wall above was reset with new firebrick and R&I #3000, thin joints being made, excess cement troweled back and the surface entirely wash-coated. This job has since stood up under severe service for a long time without breakdown.

BOOKS

1—Explosion and Combustion Processes of Gases

By Wilhelm Jost

Translated by Huber O. Croft

621 pages Price $7.50

This book is primarily a work of reference for those engaged in research in combustion, detonation and explosion, and an idea of its scope can perhaps best be had by enumerating the successive chapters. These are: Initial stages of explosions as a thermal phenomenon; thermal theory of spark ignition; propagation of explosions (including limits of ignition, normal velocity of combustion and influence of mixture); explosions in closed chambers; detonation; flames of gases not premixed; flame temperatures; radiation investigations of flames; kinematics of combustion; combustion of oxygen-hydrogen mixtures and of carbon monoxide; spark ignition; combustion of hydrocarbons (both in the flame and by slow oxidation); the ignition of hydrocarbons at high pressures; and combustion in both the Otto and diesel cycles.

2—A.S.T.M. Methods of Chemical Analysis of Metals

412 pages 6 × 9 Price $4.50

The 1946 Book of A.S.T.M. Methods of Chemical Analysis of Metals, which replaces the earlier 1943 edition, gives in their latest form the 35 extensive standards developed by the A.S.T.M. committees concerned with the analyzing of metals and their alloys. This greatly expanded volume includes not only modernized versions of the various older methods widely used throughout industry, but it includes several of the newer photometric methods and also spectrochemical methods of analysis for certain materials and elements.

There are recommended practices covering apparatus and reagents and photometric methods; methods of sampling and chemical analysis of steel, cast iron, wrought iron, etc., are included, together with methods of sampling and analyzing ferro alloys. A considerable portion of the new volume is devoted to nonferrous metals, including sampling, chemical analysis and photometric method covering aluminum, magnesium, copper, lead, lead and tin-base alloys, solders, zinc and nickel.

3—Thermodynamics

By G. A. Hawkins

436 pages $8^1/_2 \times 5^3/_4$ Price $4.50

Drawing on his broad background in teaching at Purdue University, as well as in the practical application of thermodynamics in engineering, Professor Hawkins has turned out an excellent text. Emphasis has been placed on those concepts and applications that his experience has shown to be of most value to the engineer in the practice of his profession.

By adopting the current usage of solved problems to illustrate the points under discussion, clarity is imparted to both students and to engineers renewing their familiarity with the subject. This value of the book is further enhanced by a comprehensive and well-arranged index and by the inclusion of the fundamentals of heat transmission.

4—Applied Atomic Power

227 pages 6 × 9 Price $4.00

This book is written with the object of informing the layman in relatively simple language, that can be understood by careful reading, what atomic power is. It traces in an elementary way the development of atomic energy from early work in radioactivity to its present-day scientific status, and reviews the possibilities, in so far as we know them, of the application of atomic power to industrial progress.

The various terms, such as isotopes, transmutation, fission, chain reactions, moderator and pile, frequently referred to in connection with the subject of atomic or nulcear energy, are defined and explained. The physical background of atomic energy production in the earlier part of the book prepares the reader for the summary of the development of atomic energy leading to the atomic bomb, which is dealt with in the following section. This section gives a summary of the progress at various stages throughout the war period and includes an explanation of the separation of the uranium isotopes by various methods. The next section covers some possible methods of converting atomic energy into mechanical power and the last part of the book enumerates some of the benefits which industry might expect from the engineering principles, new and improved equipment and new methods that have been developed as a necessary prerequisite of the atomic bomb.

The appendices include a résumé of the work on the atomic bomb, a conversion table for energy units and a table of nuclear and atomic masses of isotopes.

5—Heating and Air Conditioning (6th Edition)

By J. R. Allen, J. H. Walker and J. W. James

667 pages 6 × 9 Price $5.50

This is an excellent and thoroughly up-to-date textbook. It offers the student or layman a solid theoretical ground-work in domestic and industrial heating and air conditioning and provides him with some knowledge of present practice.

No revolutionary changes have developed since the last edition of this book appeared seven years ago and much of the previous text has been retained. However, numerous additions and changes have been made to both text and illustrations to bring the book into complete accord with recent development and current practice. The chapter on Fuels and Boilers has been extensive revised, while those on Gravity Warm-Air Furnace Heating and Residence Air Conditioning have been revised to include the latest rating formulas and design procedures of the industry. A new section on panel heating is included and consideration is also given to the principle of a reversed-cycle refrigeration system.

The book is written in a clear and cogent style and covers all the essentials of the subject in 23 chapters, many of which include problems and a bibliography.

6—Fuels, Combustion and Furnaces

By John Griswold

496 pages 6 × 9 Price $5.50

This is essentially a textbook, written and arranged more particularly to meet the needs of students in chemical engineering.

The technology of fuels of various types, both natural and manufactured, is adequately covered, as is also the theory of combustion processes. Fuel-burning equipment and steam generation are briefly covered.

At the end of each chapter is a list of supplementary references and problems for the student.

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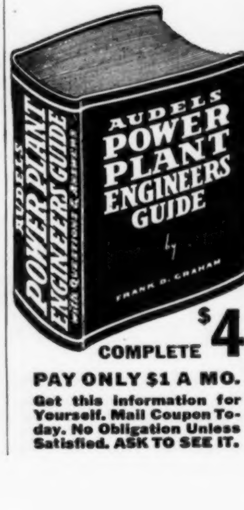

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